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الجامعة الأردنيـــــة
كلية الدراسات العليا

التاريـــخ: / /

نموذج رقم (١٨)
اقرار والتزام بالمعايير الأخلاقية والأمانة العلمية
وقوانين الجامعة الأردنية وأنظمتها وتعليماتها
لطلبة الماجستير

أنا الطالب: [illegible] الرقم الجامعي: (٨٠٩٠٩١٩)

تخصص: [illegible] الكليـــــة: العلوم

عنوان الرسالة: Modeling seawater intrusion into Rosetta branch, Nile River delta, Egypt

اعلن بأنني قد التزمت بقوانين الجامعة الأردنية وأنظمتها وتعليماتها وقراراتها السارية المفعول المتعلقة باعداد رسائل الماجستير عندما قمت شخصيا" باعداد رسالتي وذلك بما ينسجم مع الأمانة العلمية وكافة المعايير الأخلاقية المتعارف عليها في كتابة الرسائل العلمية. كما أنني أعلن بأن رسالتي هذه غير منقولة أو مستلة من رسائل أو كتب أو أبحاث أو أي منشورات علمية تم نشرها أو تخزينها في أي وسيلة اعلامية، وتأسيسا" على ما تقدم فانني أتحمل المسؤولية بأنواعها كافة فيما لو تبين غير ذلك بما فيه حق مجلس العمداء في الجامعة الأردنية بالغاء قرار منحي الدرجة العلمية التي حصلت عليها وسحب شهادة التخرج مني بعد صدورها دون أن يكون لي أي حق في التظلم أو الاعتراض أو الطعن بأي صورة كانت في القرار الصادر عن مجلس العمداء بهذا الصدد.

توقيع الطالب: .... التاريخ: / /

تعتمد كلية الدراسات العليا
هذه النسخة من الرسالة
التوقيع .... التاريخ ....

MODELING SEAWATER INTRUSION INTO ROSETTA BRANCH, NILE RIVER DELTA, EGYPT

By
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This Thesis was submitted in Partial Fulfillment of the Requirements for the Master's Degree of Science in Integrated Water Resources Management

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COMMITTEE DECISION

This Thesis/Dissertation (Modeling Seawater Intrusion into Rosetta Branch, Nile River Delta, and Egypt) was Successfully Defended and Approved on 19/1/2010

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Acknowledgement

First and foremost, I want to praise and thanks give to Allah, the Lord of everything, who is credited with all of the completion of this work.

This work is completed with assistance of a number of people and organizations, all of whom I grateful acknowledgement. I would like to express my sincere thanks and appreciation to all people who directly or indirectly contribute to the complement of this study.

I would like to deeply acknowledge Professor Abbas Al Omari and Professor Lars Ribbe for their supervision and kind help during the time I do my thesis. I wish to thank Professor Amal El Sherbini, Professor Nahla Sadek, and Professor Ahmed Fahmy for providing me with the required data for running the model in the modeling part for my thesis. I am thankful to Ministry of water Resources and Irrigation, Ministry of Environment, and all my colleagues at CCC especially Chemist Mohamed Labib, Engineer Haidi El-Henawy and Dr. Abdallah Ellithy- my senior in CCC, Egypt.

I also wish to express my gratitude to the Students of ITT who were helping and supporting me, especially Viet, Islam, and Wefaq – PhD students, Inam and Cam – MSc. Students - for their academic guidance and thoughtful encouragement.

Finally, I am grateful my family for their encouragement and for the way they overcome the difficulties during the time I was away.

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List of abbreviations:

SLR	Sea Level Rise
SWI	Saltwater Intrusion
HD	Hydrodynamic
AD	Adverse Advection
IWRM	Integrated Water Resources Management
BCM	Billion Cubic Meters
MCM	Million Cubic Meters
HAD	High Aswan Dam
ISO	International Organization for Standardization
IPCC	Intergovernmental Panel on Climate Change
UNEP	United Nations Environment Programme
WHO	World Health Organization
GWP	Global Water Partnership
DHI	Danish Hydraulic Institute
NAMRIA	National Mapping and Resource Information Authority
CCC	Cairo Central Center Laboratory
MSEA	Ministry of State for Environmental Affairs
QC	Quality Control
QA	Quality Assurance
SMWW	Standard Methods for Examination of Water and Wastewaters
APHA	American Public Health Association
ECRI	Environment and Climate changes Research Institute

NRI Nile Research Institute

NWRC National Water Research Center

MWRI Ministry of Water Resources and Irrigation

EC Electrical Conductivity

TDS Total Dissolved Salts

RMSD Root Mean of Squares of Differences

RMSE Root Mean Square Error

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Abstract

Saltwater intrusion is a key issue for the River estuaries located on a sea or ocean as the high water salinity is a key character for the freshness of water quality. One - dimensional time-independent finite difference model was used to simulate the impact of Sea Level Rise (SLR) on the water quality of Rosetta branch water quality in terms of Cations and Anions - Electrical Conductivity (EC) in practical. This research indicates the process of Seawater Intrusion and illustrates to what extent the saltwater intrudes from the Mediterranean Sea. MIKE11 model was used in order to assess the Impact of SLR on the upstream of the barrage of Idfina water salinity and to predict with the future impacts of SLR scenarios namely 0.5m and 1.0m above the current sea water level.

Chronological field investigation data for EC and water discharge were used in the study to illustrate the water salinity trend in the Rosetta branch. Idfina barrage prevents invasion of the salty water comes from the sea, but saltwater from the sea downstream invades the fresh upstream of Idfina barrage in time of opening.

The results also help to take the water quality as a serious issue to avoid saline water intrusion and its impact on socio-economic activities especially after water scarcity problems in the world.

Keywords: Saltwater intrusion modeling, water quality monitoring, MIKE11 model, surface water salinization.

CHAPTER ONE INTRODUCTION

1.1. Background

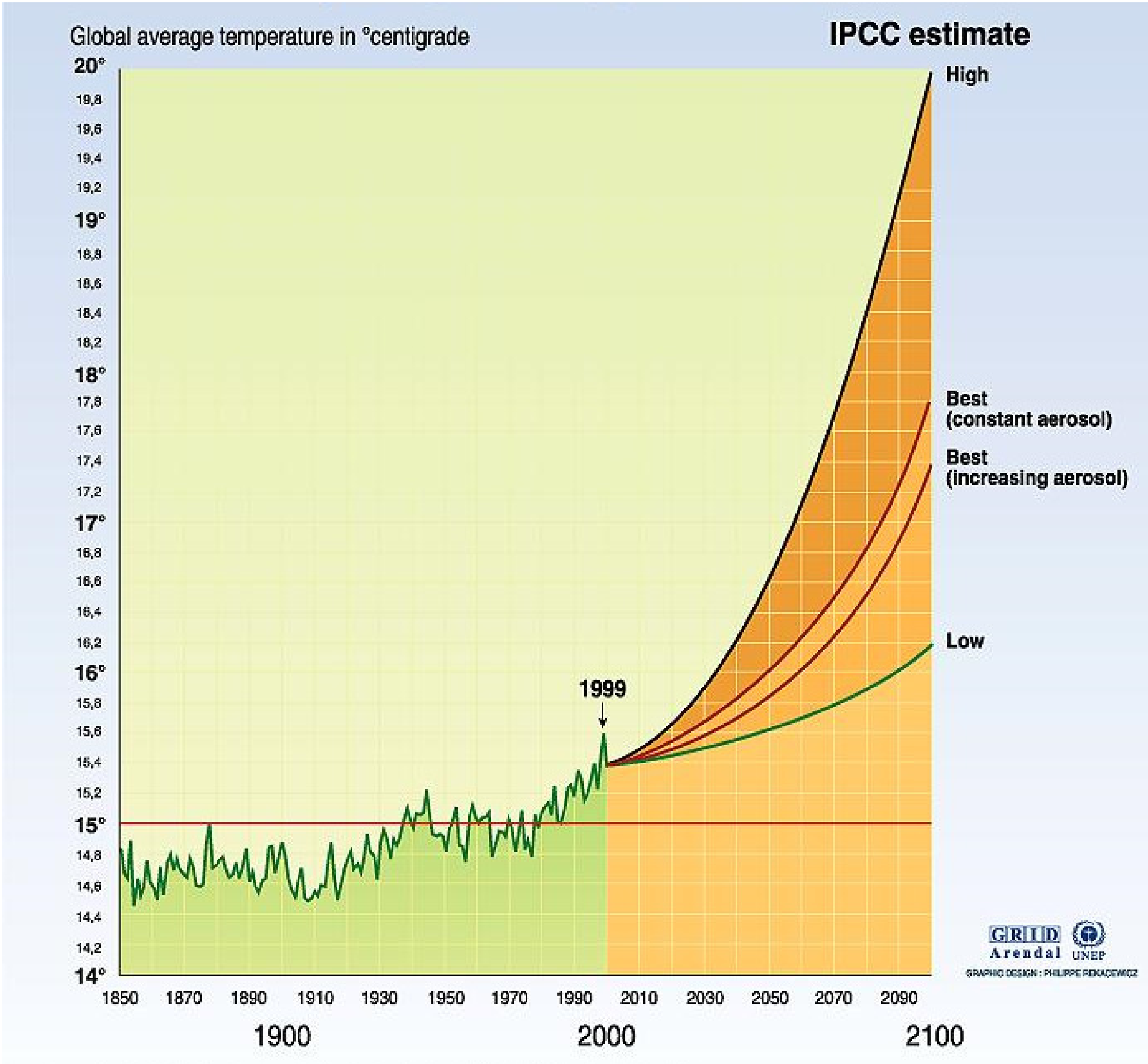
Climate change is unmistakable in the increase of the earth's averaged global warming. It mainly results from the increase of the concentration of greenhouse gases in the atmosphere, which absorbs, reflects and partially re-radiates the terrestrial long wave radiations, preventing it from leaving the earth's atmosphere. Climate change is due to Global warming and its impacts on fresh water resources quantity and quality is the dilemma of the coming years. Global averaged air temperature has recently been rising. According to the Intergovernmental Panel on Climate Change; IPCC 2007, the temperature increase is expected to continue throughout this century, as shown in Figure (1-1). However, uncertainties in the temperature predictions are still quite large about 2 degrees Celsius. The uncertainties result from the difference in the implementation method of individual physical processes among different climate models.

From examining long-term global mean temperature records from the year 1856 to the year 1999, it has become clear to – and accepted by – the scientific community that the global mean temperature has increased by 0.6˚C over the 20th century, as shown in Figure (1-1). The records which were observed for 143 years show that the warmest year on record was 1998, with surface temperatures averaging 0.55˚C above the 1961–1990 annual average (IPCC, 2007). Moreover, there are predictions of dramatic increase in the average world temperatures over the next 100 years and serious harm resulting from the predicted temperature increases.

One important and serious consequence of global warming is Sea Level Rising which is a serious problem especially in the coastal cities (IPCC 2001). There are three

main natural phenomena contributing to Sea Level Rising which are; Ocean thermal expansion, glacial melt from green lands and Antarctica, and other ice sheets (Elsharkawy, Rashed and Rached, 2009).

Global average sea level has been raising and there is a high confidence that the rate of the rise has increased in the period between mid-19th and mid-20th centuries. The average of the rising was 1.7±0.5 mm/year for the 20th century, 1.8±0.5 mm/year in the period between1961 and 2003, and 3.1±0.7 mm/year in the period between 1993 and 2003 (Bates et al., 2008).



Source : Temperatures 1856 - 1999: Climatic Research Unit, University at East Anglia, Norwich UK. Projections: IPCC report 95.

Figure (1-1) projected changes in global temperature: global average (1856-1999) and projection estimates to 2100.

1.2. Sea Level Rise impacts on coastal zones:

There are many impacts on the coastal areas due to SLR, (Cap-Net, WMO/APFM, UNESCO-IHE, REDICA and Rhama, 2009), these impacts include:

a) Lowland inundation and wetland displacement

b) Altered tidal range in rivers and bays

c) Changes in sedimentation patterns

d) More severe storm surge flooding

e) Increased saltwater intrusion into estuaries and freshwater aquifers

f) Increased wind and rainfall damages in regions prone to tropical cyclones.

1.3. Water quality changes due to Climate Change:

Runoff variation and high temperature of water are likely to produce adverse changes in water quality affecting human health, ecosystems, and water use. Lowering of the water levels in rivers and lakes due to evaporation will reflects in many phenomena such as re-suspension of bottom sediments and liberating compounds with negative effects on water supplies. However, pollutants will easily introduce. Moreover, higher runoff increases the nutrients and sediments, coupled with lower water levels, will negatively affect water quality. Furthermore, a higher water temperature enhances the transfer of volatile and semi-volatile compounds (e.g., ammonia, mercury, dioxins, and pesticides) from surface water bodies to the atmosphere.

Salinity as an important factor resulting from high water tempetature will increase in estuaries and inland reaches with decreasing stream flow by evaporation. The tributary rivers above irrigation areas in the Murray-Darling Basin, Australia shows increase in salt concentration by 13-19% in 2050 and by 21-72% in 2100. Water Stalinization is expected to be a major problem in small islands suffering from coastal sea water intrusion and in semi-arid and arid areas with decreasing runoff. Due to sea-level rise, groundwater Stalinization will very likely be increased. (Kundzewicz 2007).

1.4. Problem statement:

In Egypt, the potential impacts of sea level rise will be on the Nile Delta. The impacts are expected to include a decline in water quality that would affect the freshwater, the flooding of agricultural land and lastly damage to infrastructure. Figure (1-2) shows the Nile Delta region for three different -cases- scenarios. The current status, Fig (1-2-a), is presenting the situation in the year 2002. The other scenarios show the potential impacts of SLR namely for 0.5 m and 1.0 m sea level rise, as shown in Fig (1-2-b) and Fig (1-2-c) respectively. It is obviously shows that the Sea Level Rising has clear consequences and impacts on different scales within the coastal cities or areas.



Figure (1-2) satellite maps of Nile Delta- north of Egypt, showing the potential impacts of SLR with (a) the occurring status in 2002, (b) and (c) the projected coastal inundation with 0.5m and 1m SLR. (Elsharkawy H., Rashed H., & Rached I., 2009)

For 0.5m SLR 26% of the Rosetta region is expected to be inundated and that area includes 32% urban clusters, i.e. monuments, residential areas, public utilities, active industries, and all governmental and administrative blocks, and 25% highly fertile land used for cultivation of high quality dense palm trees. Also it is projected that 72% of the area will be inundated as a result of 1m SLR and 43% of urban clusters are going to be lost (El-Raey et al. 1997).

It is well known that, the Delta region in the northern part of Egypt is very fertile and heavily cultivated, but the soil salinity and expected inundation of a vast area of that

land due to sea level rise will create a dilemma in terms of food production, reduction of cultivated lands, and grain production (Abou-Hadid, A.F., 2006). Also, severe increase in the crop prices - especially the imported crops - not only because of climate change and expected water resources defect - due to climate change - but also because of demographic explosion. Consequently, the demand on food production is going to be increased (Elsharkawy H., Rashed H., & Rached I. 2009).

Moreover, the expected socio-economic impacts of SLR should not be ignored. Economic activities in Rosetta area are going to be lost as well as expected losses in the employment sector due 0.5m SLR. The losses estimated based on statistical distribution of employment in each sector as shown in Table (1-1) (El-Raey et al. 1997).

Table (1-1) Estimation of expected loss in employment and jobs sector resulting from a 0.5 m rise in sea level.

Sectors of economic activities	Actual population ($*10^3$)	Expected loss (Per job per person)
Agriculture and fishing	18.5	4633
Convertory industries	4.5	502
Municipal utilities (Electricity, gas, and water supplies)	139	78
Construction and buildings	1 355	433
Commercial	2 877	1640
Transportation	2 191	1248
Community services	6 275	3576
Total	35 936	12,110 (33.7% of total employment)

SLR has also direct impacts on the natural resources. It affects the soil properties and the fresh water resources either groundwater or surface water. Salt water intrusion hurts

the fertile lands and increases the salinity of fresh waters. The salinity measurements for the River Nile water have been made in the Delta region (For Rosetta branch). It has been shown that, closer to the Mediterranean Sea, salinity in the drainage water increases, until reaching a concentration close to 10,000 mg/l near the coast, and this occurs as a reason for that; the Rosetta branch is creating the mouth of the Nile River on the Mediterranean Sea. Increasing salinity in the fresh water either ground or surface water leads to a sophisticated dilemma currently or for the coming generation (Marwa Ali, 2007).

1.5. Study area:

Egypt is an arid country which depends almost entirely on the River Nile as a resource of water supply. It is estimated that the Nile River provides about 97% of the country's fresh renewable water supply. The majority of the country area is desert land. The Nile Valley and its Delta occupy only about 4% of the total country area.

Nile River has two branches and Rosetta branch is larger than Damietta. Rosetta branch was used before the establishment of the High Aswan Dam (HAD) built up as a discharge way to effluent the flood waters to the Mediterranean Sea. After the establishment of the HAD, the amount of water discharged into the sea gradually decreased. Development process management for water conservation, and system modification of the winter blockage; the amount of water that is dumped into the sea annually decreased from several billions of cubic meters yearly to 0.1 billion m^3/ year. This leads to stopping of navigation almost along the Rosetta Branch, and a major focus on water management policies in Egypt continued reduction of the quantities of fresh water discharged to the sea and to increase water resources and wastewater re-use (either agriculture or domestic wastewater).

1.5.1. Location:

The River Nile runs about 1000 km inside Egypt. To the north of Cairo, the capital of Egypt, by about 25 Km at Barrage, the River Nile bifurcates into two branches, namely, Damietta and Rosetta branches. The Rosetta branch, represents the area of investigation; lengths about 231 Km., the width of the branch varies from about 150 meter to 200 meters and the average depth ranging between 2 and 4 m. Figure (1-3) shows the river Nile in Egypt and in focus Rosetta Branch.

Since High Aswan Dam was built in 1964 on the Egyptian Nile upstream in Aswan, Nile water discharges through the Damietta Nile branch has almost stopped, but the Rosetta Nile branch is still discharging into the Mediterranean Sea through four coastal lakes: Manzala, Burullus, Mariut and Edku (Marwa Ali, 2007).

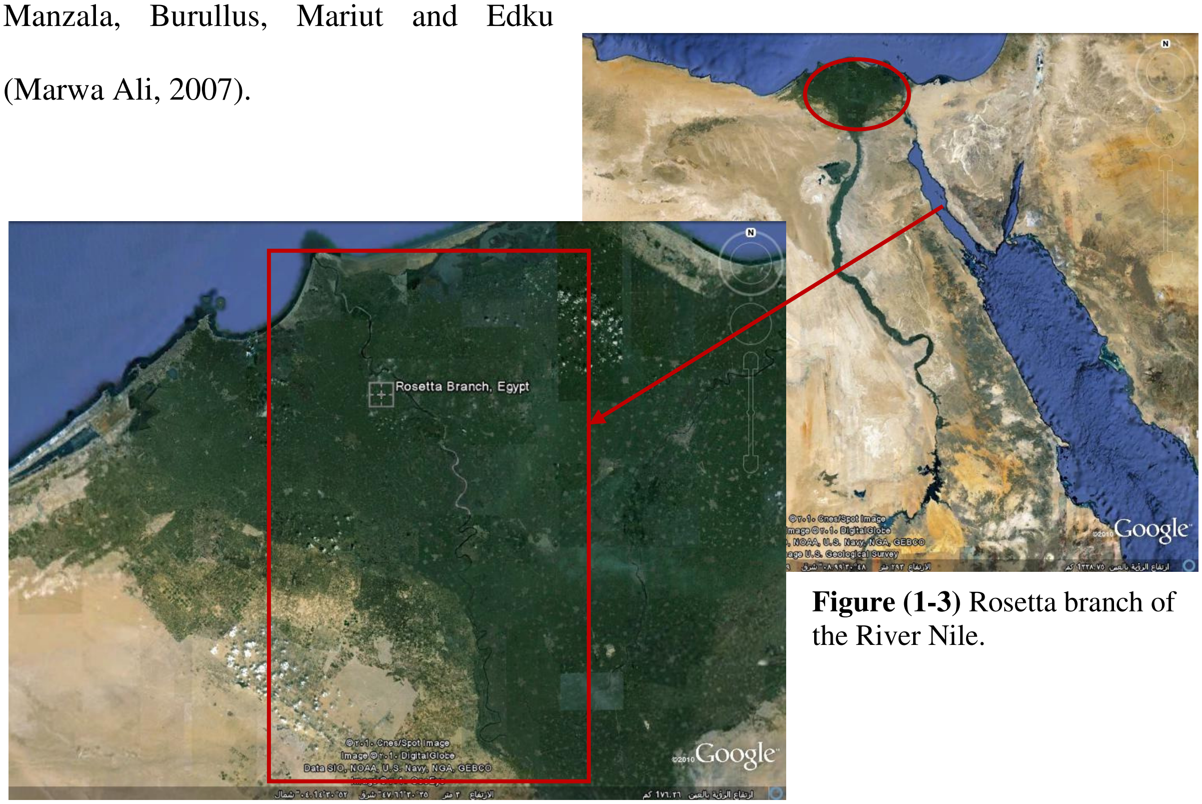


Figure (1-3) Rosetta branch of the River Nile.

1.5.2. Land use:

The Nile River provides the surrounded area with soil fertility that facilitates the development for the famed ancient agricultural civilization. Traditional cultivated lands are predominating in the eastern part of the Western Nile Delta region. One the other hand, reclaimed lands are present on the western fringes of the region using surface water, groundwater or conjunctive use of irrigation water. High density of built towns and villages with high population cover this area from the Nile Delta. All towns and villages are connected by railways and motor roads with a large scatter of different industrial areas.

1.5.3. Climate:

Egypt's Climate is semi-desert, characterized by hot dry summers, moderate winters and very little rainfall. The Climate in Egypt has been changing in phase with global change, but with lower rates of variation. There is a downward trend in maximum temperature over the delta, starting from the northern part of Upper Egypt; and it is extreme on the south of Upper Egypt. This downward trend has ranged from -0.02°C to -0.06°C/year. Minimum temperatures have markedly increased over Egypt. Increasing temperature by +0.05°C /year over the western part of Delta near the Mediterranean Coast and this rise at night time may be due to the effect of greenhouse gases and the increasing water vapor in the boundary layer. Moreover the rise in surface air temperature in Egypt is about 40% of the global rise in surface air temperature (EEAA report 1999).

1.5.4. *Sources of pollution in Rosetta Branch* (El Gammal and El Shazely, 2008):

Rosetta Branch receives relatively high concentrations of organic compounds, nutrients and oil & grease. Major sources of pollution are El Rahawy Drain (receives part of Greater Cairo wastewater), Sabal Drain, and Tala Drain. The most important causes of

major pollution on the Rosetta Branch is the agricultural Drains, it discharges directly its wastewater on Rosetta Branch, as well as salt and soda companies and the Egyptian Financial and Industrial Company located in Kafr El-Zayat city in Gharbeya governorate which discharges industrial wastewater resulting from the production of fertilizers and its co-products. It is clear from the results of analyses for the taken samples from drainage water that the water is polluted at the final discharge point before reaching Rosetta Branch; which might be due to the following reasons:

a) Most of the Drains receive mixture of agricultural, industrial, and sewage wastewater and this mixture contains a high percentage of dissolved and suspended solids, and also high content of oils, organic matter, and nitrogen.

b) El Rahawy Drain represents the most serious source of pollution at Rosetta Branch water, because it receives the largest bulk of sewage and industrial wastewaters from Greater Cairo area which imbed three governorates (Cairo, Giza, and Kalyoubeya).

It is worth to mention that, the continuity of discharging polluted water to the Rosetta branch directly without appropriate treatment will lead to the deterioration of environmental situation in Rosetta branch. The following are the main Drains that are considered to be the main pollution source on Rosetta branch:

1.5.4.1. *Sabal Drain* (74 Km away from Delta barrage):

The Drain discharges directly on Rosetta Branch with a total disposal of 2.4 MCM/day, carrying sewage wastewater from the cities of Menouf and Shebin wastewater treatment plants as it is not authorized from the governmental authorities to dispose their wastewater to Rosetta branch. The National Authority for Drinking Water and Sanitation

intends to accommodate six stations for the treatment of sewage water, and that will represent more loads on the Sabal Drain, consequently on Rosetta branch.

Sabal Drain Discharges about 68.4 MCM/year of sewage wastewater at 70 km behind the Delta Barrage close to Menoufia governorate which serves cultivated land estimated by 140 thousand acres in Menoufia governorate.

1.5.4.2. *South Tahrir Drain* (85.5 Km away from Delta barrage):

South Tahrir Drain directly disposes considerable amounts of wastewater to the Rosetta branch; these amounts are estimated by 0.66 MCM/day on Rosetta branch.

1.5.4.3. *Tala Drain* (119.4 Km away from Delta barrage):

Tala drain receives untreated and partially treated wastewater from Tala, El-Shohada, and El Kom El Akhdar. The primary treated wastewater is 72,000 m^3/day approximately.

1.5.4.4. *Elrahawy Drain* (9.85Km away from Delta barrage):

El Rahawy drain receives about 400,000 m^3/day primary treated wastewater from Abo Rawash Wastewater Treatment Plant beside 600,000 m^3/day untreated wastewater as a bypass from this plant. It also receives 430,000 m^3/day of secondary treated wastewater from Zeinen Wastewater Treatment Plant.

At Kafr El-Zayat city, Rosetta branch receives also industrial effluents from fertilizers and Salt and Soda companies. Further more, Rosetta branch receives also drainage water from agricultural areas fertilized by animal manure and chemicals. As a result, there is a marked increase of phytoplankton (floating and submerged aquatic plants) production in Rosetta branch.

1.6. Justification of the study:

The part of the Rosetta branch from the Idfina barrage to the mouth of the river at the north in the Mediterranean Sea lengths about 25Km, is neither used for drinking nor for agricultural purposes. The properties of water quality in this part of the branch resemble that of the Mediterranean Sea due to the seawater invasion. The barrier between this part of Rosetta branch and the fresh water is the barrage of Idfina (shown in the figure (1-4)). This barrage is considered as a shield protecting Rosetta branch fresh water from the salinity intrusion towards the upstream of the barrage. But due to the point sources of pollution downstream in the Delta barrage as indicated in a previous section (1-4), it is needed urgently to open the Idfina barrage in order to get rid of those the effluent pollutants. In turn, salty water from the sea, downstream, can invade the fresh water, upstream the barrage of Idfina. This study shows the danger of the Barrage of Idfina opening, in term of water salinity, and what could happen after opening the barrage of Idfina. Moreover, if the situation continues, it will be easy to expect what could happen for the Rosetta branch water salinity in case increasing the sea water level as the worst two future scenarios, namely 0.5m and 1m SLR. From the results the problem now is clear infront of the decision makers who know how to stop this catastrophe and find out the appropriate adaptation options for the worst of the future scenarios.

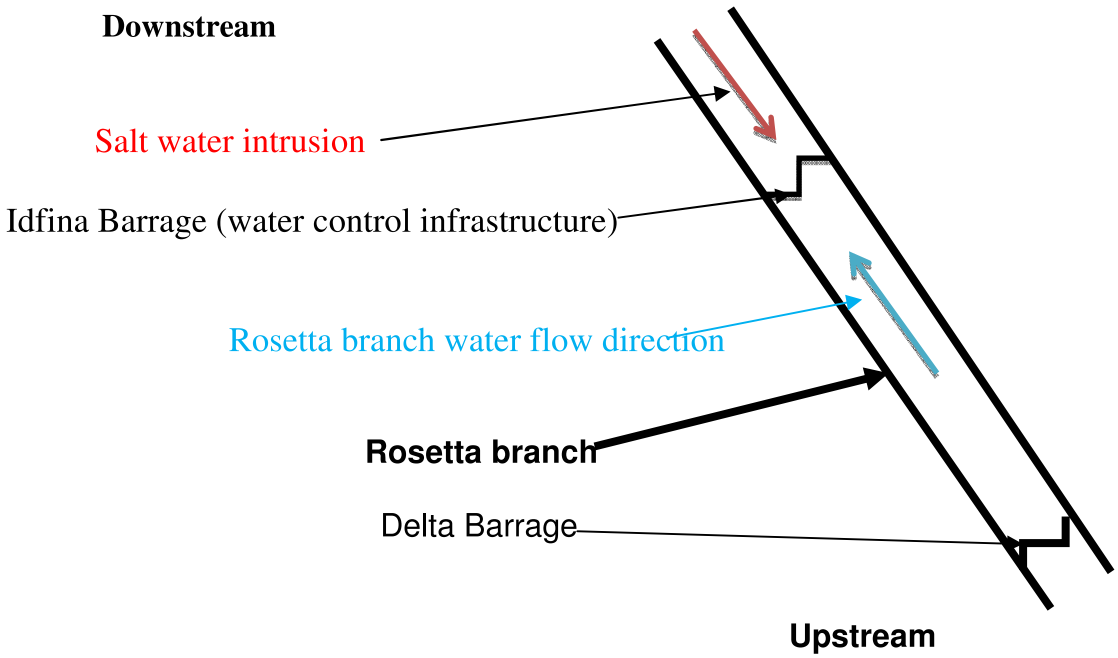


Figure (1-4) Sketch shows the water flow and the sea water flow in the Rosetta branch

1.7. Importance of the study

It is obvious that the water scarcity problem in Egypt is serious and especially after the future threats of the climate change on the scarce water resources. The impacts of climate change in upstream of the Nile River and rising of sea level will be more challenging for Egypt's water resources in the near coming future.

This study will be the first to deal with modeling of seawater intrusion in Egypt and will be helpful to predict the changes in Electrical Conductivity (EC) of the Rosetta branch at the Nile Delta for different Sea Level Rise scenarios due to climate change and also predicting to which point the seawater will invade upstream. In turn it helps us to adopt the appropriate adaptation measures to mitigate the negative impacts of SLR.

1.8. Objective of the study

The study objective is to enhance the value of water resources and the best way to deal with the future threats based on in sight information and indications. The best way to protect primary water supply sources is to ensuring adequate water supplies for current and future water use. From this point, the purpose of this study is to assess the current salinity in Rosetta branch of the Nile River and the impact of sea water intrusion on the Rosetta branch water salinity for the projected two scenarios namely, 0.50 m and 1.00 m SLR.

CHAPTER TWO LITERATURE REVIEW

2.1. Background:

A brief overview about water resources in Egypt with its facing challenges is mentioned in this chapter. As well as, concise about the role of Integrated Water Resources Management (IWRM) for addressing climate change is also mentioned. Then, Sea Level Rise, types of Mouth Rivers, saltwater intrusion and some factors contributing the process of saltwater intrusion are further discussed. Afterwards introducing a general idea about one-dimensional hydrodynamic modeling and saltwater intrusion modeling using MIKE 11 model is indicated. Finally, some previous studies related to saltwater intrusion into the River estuaries are summarized.

2.2. Water resources in Egypt:

Egypt receives more than 95% of its various fresh water resources from outside its international borders. Nile River is considered to be the main fresh water resource. Egyptians are relying on it to meet their requirements in terms of water needs. The average annual yield of the river is estimated around 84 Billion Cubic Meters (BCM) at High Aswan Dam (HAD). Nevertheless, Egypt's annual share of the river water is determined by international agreements by 55.5 BCM (Bayoumi B. Attia, 2004).

Rain water is a very limited resource for fresh water over Egypt but only it falls in the northern coastal zone area along the Mediterranean shore line especially in winter season. The total amount of rainfall does not exceed 1.5 BCM per year. Also, flash floods occurring due to short-period of heavy storms that are considered as water resource especially in the Red Sea area and Southern Sinai.

Groundwater is considered a limited freshwater resource as it comes from the percolation of the water from the Nile River, irrigated land, and seepage of water from the irrigation canals. It is estimated to be 7.5 BCM per year. Figure 2.1 shows the quantities of Egypt's water resources.

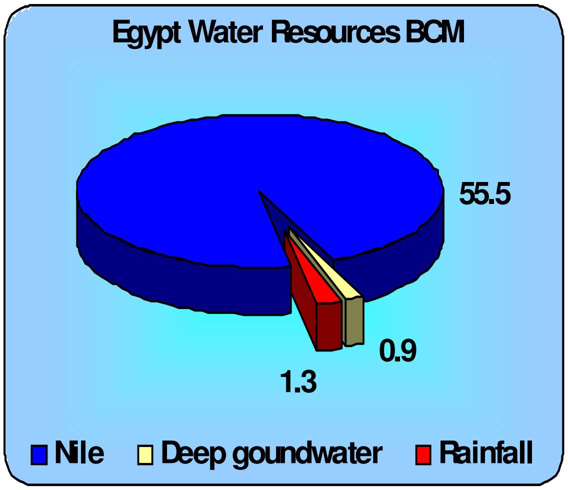


Figure (2-1) **Egypt's Water Resources**
Sources: (Bayoumi B. Attia, 2004)

Reuse of the agricultural and municipal wastewater as well as desalinated seawater and rain water harvesting is considered as a non-conventional water resource. The desalinized water is estimated by 1 BCM per year and the municipal wastewater is estimated by 0.7 BCM per year (Bayoumi B. Attia, 2004).

2.2.1. Rosetta branch water demand:

The present monthly water demand for Rosetta Branch is studied in the period from 1996 to 2006. Figure (2-2) shows the total monthly demand for Rosetta Branch in addition to the average monthly demand for 2008. It can be concluded from this figure that the minimum average water demand is at January with a value of 129.78 Million Cubic Meters (MCM) per

month and the maximum average water demand is at June with a value of 628.08 MCM per month.

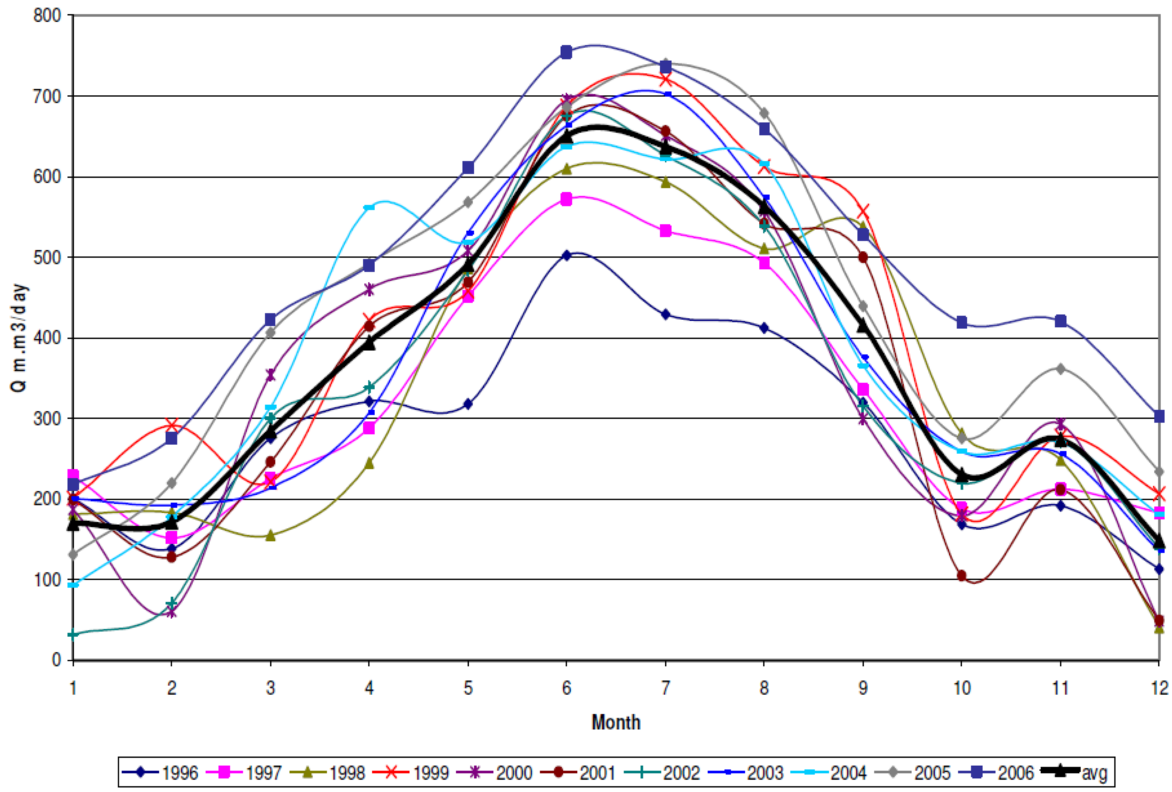


Figure (2-2) the Rosetta branch water demand (Sherine S. Ismail, 2008)

2.2.2. Water flow and dilution capacity in Rosetta branch:

With increasing the agricultural and industrial wastewater discharging on the Nile River, the dilution capacity of the Nile River system will diminish at the same time that growth in industrial effluents and municipal wastewater increase the volume of pollutants discharged to the Nile River. In particular, the average water inflow in Rosetta branch is 15.14 MCM and it differs along the year, because of the water seasonality which comes basically from the upstream countries. The ability of Rosetta branch to dilute the wastewater comes from the Drains was quite high, but is decreasing by the time, and later

or sooner this ability will vanish gradually as the water quality in Rosetta branch is deteriorating.

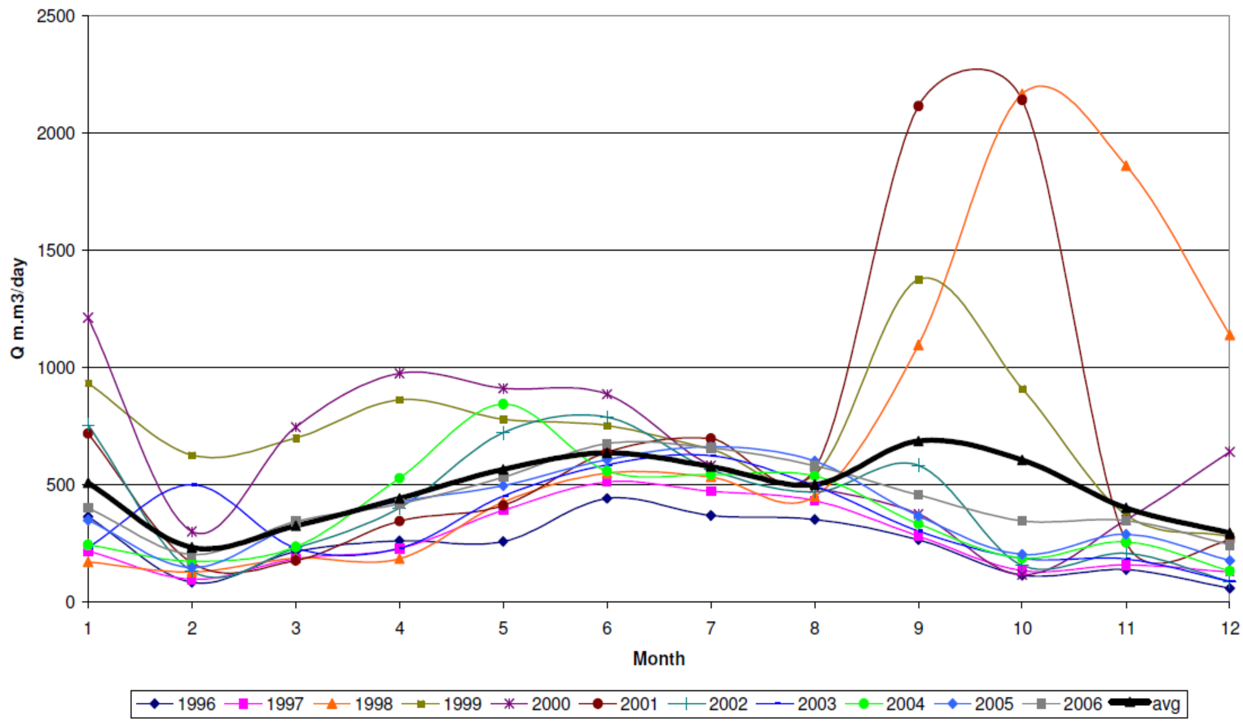


Figure (2-3) Water Releases in Rosetta branch.

Rosetta branch water releases are studied in the period from 1996 to 2006. Figure (2-3) shows the monthly water releases in this period in addition to the average of water releases during 2008. It is concluded from this figure that the maximum average of water release is at September with a value of 687 million cubic meters per month.

2.3. Challenges facing the water resources in Egypt:

There are some obstacles struggling usage of the water resources in rational way, or makes the process of water resources management not easily attained. Some of these obstacles as following:

2.3.1. Demographic explosion:

The first determinant for water resources development is the population growth where the population has tripled during the last 50 years from 19 Million Capita in 1947 to about 62 Million Capita in 1996. It is expected to be about 95 Million Capita by year 2025. Figure (2-4) shows a severe decline in the water resources versus sharp increase in Egypt's population. Egypt now fell below the water poverty line (1000 cubic meter per capita per year) before the year 2000 (Abdel-Gawad and Shaden, 2008).

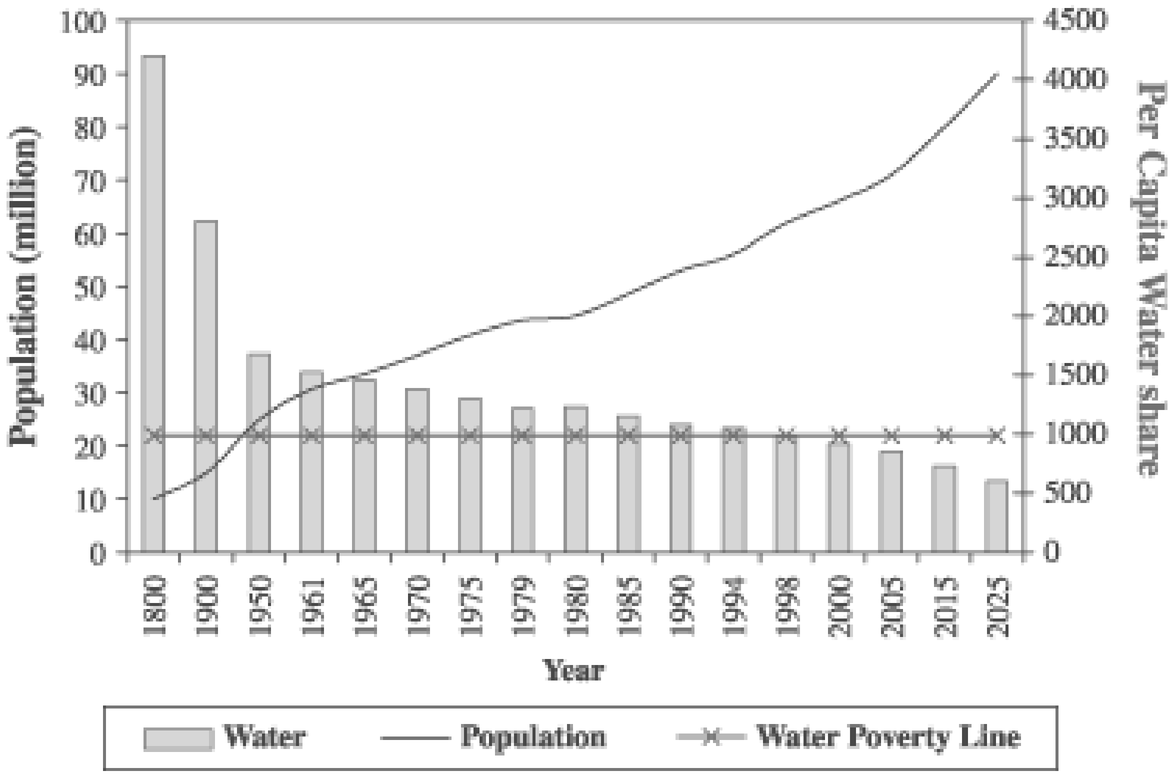


Figure (2-4) Population growth and per capita water share in Egypt (m^3/year)
Sources: (Abdel-Gawad and Shaden, 2008)

This information means that it is a must to increase the water resources to meet the people needs and it is really representing a real challenge facing the next generations.

2.3.2. Poor cost recovery

Water tariff is extremely cheap, which encourages the water users in different sectors to misuse the water in rational way although it is a scarce resources. So, it is important to set up a cost recovery system to water users' pay for water distribution and network maintenance services. Based on the IWRM guidelines, that would ensure the sustainability and water use efficiently. (Abd Al-Rahman, 2007)

2.3.3. Pollution resulted from industrial growth

One of the major issues facing Egypt is the accelerated decline of water quality. Water quality has a direct effect on the quantity available for a specific use. In turn, that deterioration in the water quality will decrease the supply and increase the gap between the demand and supply (Donia, El-Azizy, and Khalifa, 2003).

2.3.4. Low level of awareness

Lacking of environmental issues awareness related to water resources utilization is really important because that could lead to misuse of the resources and wasting it. So, it is important to the people knowledge of new technologies in farm irrigation, domestic uses to conserve water for future development and generations.

2.3.5. Climate change

Global warming, due to the enhanced greenhouse effect, is likely to have significant effects on the hydrological cycle concerning water quality and quantity. The hydrological cycle will be intensified, with more evaporation and more precipitation, but the extra precipitation will be unequally distributed around the world. Some parts of the world might have significant reductions in precipitation, or major alterations in the timing of wet and dry seasons.

The Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) warned that global warming would lead to increases in both floods and droughts. Moreover, there are both supply-side and demand side pressures as a result of climate change. The supply-side pressure includes climate change (reducing or increasing the amount of water available). Demand-side pressure includes population growth is leading to increase demands for several purposes; domestic, industrial and agricultural water (Nigel, 1999).

2.4. Water quality monitoring

Monitoring and assessment of water quality for Rosetta branch is very crucial in order to evaluate the current salinity situation, on the hand, to detect the current extent of the saltwater intrusion towards the upstream in the branch.

Monitoring is defined via the International Organization for Standardization (ISO) as: “the programmed process of sampling, measurement and subsequent recording or signaling, or both, of various water characteristics, often with the aim of assessing conformity to specified objectives” (Water Quality Monitoring 1996 UNEP/WHO). This general definition can be differentiated into three types of monitoring activities that distinguish between long-term, short-term, and continuous monitoring programs as follows: Monitoring is the long-term, standardized measurement and observation of the aquatic environment in order to define status and trends, Survey is a finite duration, intensive programs that measures and observes the quality of the aquatic environment for a specific purpose, and Surveillance is continuous, specific measurement and observation in purpose of water quality management and operational activities (Water Quality Monitoring 1996 UNEP/WHO).

In that regard and for detecting the current salinity situation in the branch; it is necessary to set up a survey program.

2.5. IWRM participation for addressing climate change problem:

The Global Water Partnership defined IWRM as "IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order maximize the resultant economic and social welfare in an equitable manner without compromising sustainability of vital ecosystem" (GWP 2000).

IWRM proposes various tools and instruments that deal with water access, protecting the integrity of the ecosystem integrity, and safeguarding water quality for future generations. In this way, IWRM can assist the communities to find the appropriate adaptation towards the climate change conditions which limit water availability or may lead to excessive floods or droughts.

The following points are the key functions required for IWRM. These functions are considered instrumental for integrated resources management and can be helpful in coping with climate change variability. As an example:

- Monitoring water quantity and quality can proactively take action towards adaptation. This key function of IWRM is considered as one of the objectives of this research which will be explained in the methodology chapter.
- Management of floods and droughts the key function of water resources management (WRM) allows direct intervention in case of extreme events.
- In basin planning, risk assessment and adaptation measures can be incorporated.

Water can be allocated to the most effective use to react with climate variability in a flexible manner. In another words, Risks can be better identified and mitigated in the process of basin planning.

IWRM has the advantage of making the respond to water availability or scarcity easier. When actions needed, stakeholder participation helps to motivate the communities and to generate decisions and actions. Although, water users can be stimulated to use the water resources in sustainable way, it is able to face the changing in the water conditions (Cap-Net, WMO/APFM, UNESCO-IHE, REDICA and Rhama, 2009).

2.5.1. IWRM challenges in Egypt

The growing population and socio-economic activities require increasing the amount of water supply. Despite the proliferation of River Nile water, it also this source has nature limitation that will outgrow by the time. Generally, effective improvement among the water users generally might delay that point in time, but sooner or later, Egypt should face that situation. So, decisions have to be made on the susceptibility to deal with this problem. The following points are the constraints facing IWRM implementation (MWRI, 2005a):

2.5.1.1. Securing water for people:

Water is essential element for life and safe drinking water accessibility is the first requirement that has to be met. The water quality is not following the safe drinking water guidelines and the drinking water distribution systems are not secured. In the study area of Rosetta branch many of the inhabitants were complaining from the high level of salinity in the drinking water.

2.5.1.2. Securing water for food production:

Agriculture is the major economic activity in Egypt, especially in the Delta. Agriculture uses up to 95% of the total water demand in Egypt. Demand for irrigation water will increase with the population growth. However, improvement in the irrigation ways and water conveyance efficiency must be considered. In the Delta region, groundwater is renewable water source mainly because of the percolation of the Nile River water. So, it is considered a challenge for IWRM implementation.

2.5.1.3. Securing water for industry, services, and employment:

Meanwhile, agriculture consumes the main share of the Egyptian water resources, for development of other livelihood opportunities – in practical, the industrial and services sectors – are limited. In this constraint the quality of the adequate water supply is more vital than the quantity with respect to the sewage wastewater that will be produced.

2.5.1.4. Developing a strong institutional framework:

Historically, the water resources management in Egypt has been centralized and sector oriented, while, the concept of IWRM promotes decentralization, cooperation between stakeholders, and privatization. Though, it is extremely important to set up institutional systems for water management which have their separate legal and financial means to implement their tasks.

2.5.1.5. Public awareness:

Water use behavior must be changed in the light of water supply limitations and water quality deterioration. People awareness should be increased to sustain water management for the whole water sectors.

2.5.1.6. Protection and restoration the vital ecosystems:

The aquatic ecosystems in Egypt – in practical Rosetta branch (the study area) – are threatened seriously because of the water quality deterioration. It is extremely important to be rehabilitated and restored to be used for fishing, recreation, and socio-economic use.

2.5.1.7. Cooperation with Nile Basin countries:

Because Egypt is the most downstream country in the Nile Basin, it will be affected by any development in the upstream. In turn, cooperation with the Nile Basin countries is very important to insure equitable development which results in more available water for the riparian countries.

2.5.1.8. Maximizing the importance of water resources:

It is necessary to consider the political attention and commitment for developing the water resources in Egypt as one of the critical issues to be on the top of the political agenda.

2.6. Saltwater intrusion:

Saltwater intrusion is defined as “the movement of saline water into a freshwater aquifer (WRAC, 2005) and this leads to the increase of certain cations and anions concentrations in the freshwater. This occurs predominantly along coastlines where the convergence point between the river and the sea waters occurs.

Saltwater has invaded low-lying freshwater wetlands, destroying the associated vegetation and causing dieback for large areas of the Nile Deltas. Increasing in the water flow in the River channels during the dry periods can substantially reduce saltwater intrusion into the river estuaries. On contrast, reducing the water flow by irrational use of water, the problem of the saltwater intrusion would be exacerbated.

2.6.1. Classification of the River mouthes:

The mouth of a river is the place where the river flow into ocean or sea (recipient basins) and this is considered the zone of interaction or mixing of the fresh or saltwater and riverain or marine sediments.

Hydrographically, the river mouth area can be classified into two parts:

- The riverain part (Delta Rosetta branch) , where the riverain hydrological regime is predominant,
- The coastal part (Mediterranean Sea), where the marine hydrological regime is predominant.

Both parts could interact actively with each other either by intrusion of salt seawater into the river or freshening of seawater due to the river water flow.

In terms of morphology, the river mouth areas are classified into two types:

- With Delta, and those with deltas, subclassified into semi-enclosed coastal part and opened coastal part;
- Without Delta.

The figure (2-5) shows the four types of the river mouth areas. Rosetta branch area is classified under river mouth with opened coastal part (IIB).

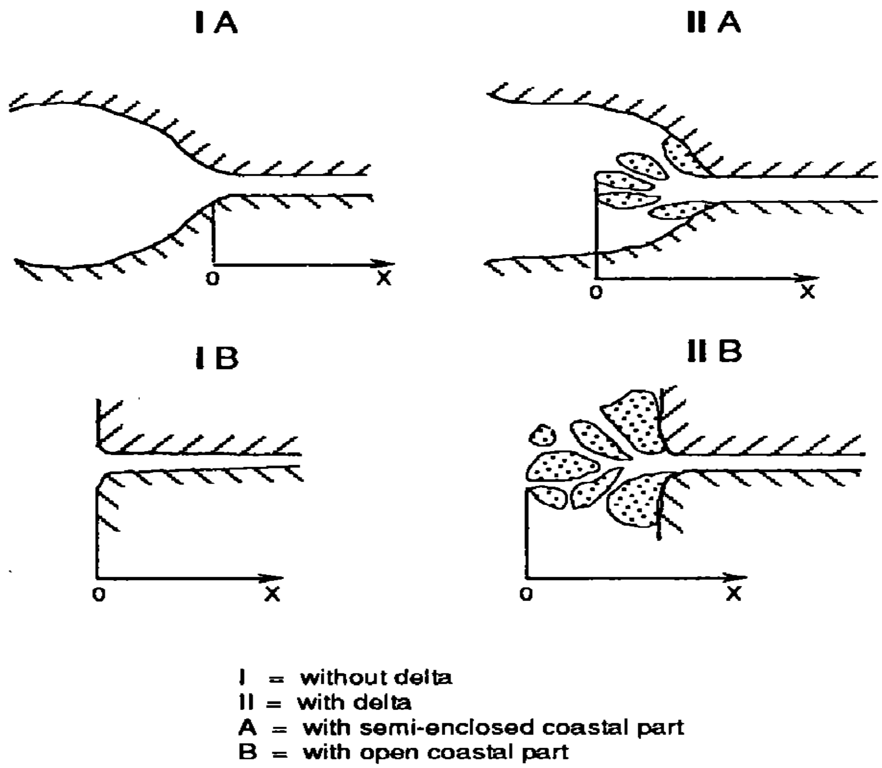


Figure (2-5) classification of river mouth areas

Sources: The working group of project 4.4b (IHP-III) & editor: H.van der Tuin (1991)

Moreover the Rosetta branch (Nile River mouth) is consedired a tidal river mouth area because the tidal range is above 0.3m.

Based on mixing between the river and sea waters, there are three types of river mouth areas will comprise; well-mixed river mouths, moderate mixed river mouthes, and river mouths with saltwater wedge. The last three categories depend on the water density, in the first type (well-mixed river mouths), the water density is constant over the depth and changing longitudinally; in the second type (moderate mixed river mouths), the water density changing over the depth and longitudinaly, and in the last type (river mouths with saltwater wedge), the water density is changing sharply at the convergence point between the river and seawaters (H.van der Tuin 1991).

2.6.2. Mouth mixing zone and saltwater intrusion into the rivers:

Regardless of the type of the river mouth area, there is a certain area where seawater and fresh river water mixed together, this area of the River mouth is called 'river mouth mixing zone'. In this area the salinity of the River fresh water increases approximately from 1% to 10% till approaches 40%.

The mouth mixing zone could be shifted into the Delta branches during the low River water discharge and high tides. In this case, seawater intrusion takes place into the riverain part of the mouth. Changing the place of mixing zones is according to some factors; the River discharge, tidal range of the sea, depth of the channel, and the salinity of the seawater. For instance, mixing in the riverain area will occur in case of smaller river discharge, water slope, and influentially the tidal range of the sea. Also the saltwater penetration distance into the river will be influentially effective and directly proportional to the tidal range of the sea. Likewise, the greater the seawater salinity, the channel depth, the high tidal range, and the smaller river discharge; the greater penetration of the saltwater into the riverain mouth. In some river mouths in case of high river discharge and narrow coastal area, saltwater will not penetrate into the river and the mixing zone, it will be situated in the coastal part of the mouth area (H.van der Tuin 1991).

In light of the previous principles, table (2-1) shows some information regarding saltwater intrusion into some tidal and non-tidal river estuaries in different countries.

Table (2-1) data about saltwater intrusion into some river mouths for different countries.

River mouth (Delta branch)	Critical river water discharge in m^3/S	Max. length of penetration of the saltwater into the river in Km
Non-tidal river mouths		

West Dvina (Duagava) (USSR)	1000-1200	27-28
Danube, Sulina branch (Romania)	1280	20-30
Lielupe (USSR)	40	45
Kura (USSR)	-	27
Kuban (USSR)	-	10-15
Don (USSR)	-	15
Yana (USSR)	2400	40
<u>Tidal river mouths</u>		
North Dvina (USSR)	10000	43-45
Onega (USSR)	750-1000	10
Petchora (USSR)	4000	5-7
Senegal (Senegal)	750	300
Mississippi (USA)	-	240
Mekong (Vietnam)	-	40

Sources: The working group of project 4.4b (IHP-III) & editor: H.van der Tuin (1991)

saltwater penetration length will be increased rapidly by decreasing the discharge of the river water. In case of the shallow river mouths; the saltwater usually does not penetrate the river mouths even with low water discharge. Although, the artificial deepening of the river mouths, no matter for what purpose, the saltwater penetrates the river estuaries. It is the case of the river mouths in West Dvina, Yana, Don, and Mississippi. The brackish water usually penetrates the tidal river mouths during low river discharges for longer distances than that in non-tidal river mouths.

2.6.3. Some factors governing the process of saltwater intrusion:

Branching of estuaries occurs when the river discharge from the upper reaches flows out into the sea through two or more tributaries which is a common feature widely observed in the world, such as in the estuarine of the Mississippi, the Danube, the Nile, Changjiang, Huanghe, Zhujiang, and other Rivers around the world. Yet the mechanisms of saltwater intrusion in branching estuaries are much more complex than in a single channel estuary. The study of forms of intrusion and patterns of salinity is important for salinity forecasting, and leads to a better utilization of fresh water resources in tidal estuaries (MAO Zhichang, et al. 2000).

2.6.3.1. Heaviness of seawater versus river water:

The salt content of the seawater is higher than that in the fresh water (river water); this makes the density of the sea water higher than that of the fresh water. Hence, there will be density difference between both waters which makes affects the flow in the estuary, where seawater is diluted by the fresh water from the river estuary (H.van der Tuin 1991).

2.6.3.2. Stratification of the river estuaries:

Due to the density differences between sea and river waters, stratification tends to be occurred in the water body, where the heavier water, with the greater density, is near to the bottom of the water body than the lighter water layer, with the lesser density, which is near the top of water surface. The energy required for stratification is supplied by the tidal flow. Stratification is most pronounced in estuaries with non-tidal sea recipient and it is weaker when the tidal action is strong (H.van der Tuin 1991).

2.6.3.3. Other factors contributing saltwater intrusion:

Several physical factors can determine, and contribute substantially, the estuarine processes driving intrusion of the salt water into the coastal lowlands and formation of the coastal plains. They include variability of climate, fluctuation in sea level, stream hydrology and morphology of the coastal plain. All the previous factors require further field survey and closer examination. In particular, evaluation and modeling of the fresh and saline water interface requires a well surveyed long profile as well as surveyed channel cross-sections to identify channel width and depth in a manner like what will be explained later on in the previous researches have been done and is going to be explained in the next chapter.

Three features of the regional climate are of direct relevance to the hydrology of tidal streams: the seasonal rainfall pattern; changes in wind direction including the frequency, and the incidence of tropical cyclones and their associated storm surge. Rainfall relates to run-off from the floodplains as well as water level within the main river systems. Winds, including those generated by tropical cyclones, affect waves, water levels at the coast and currents in the estuarine reaches of the rivers (Cobb SM, et al., 2007).

2.7. MIKE 11 model:

The basic equations in the hydrodynamic and water quality models are conservation of fluid mass equation, conservation of momentum equation, and species equation (dissolved equation). These equations are in the form of partial differential equations. Due to the irregularity of boundary and topography of the study area, analytical techniques are not available hence various numerical techniques have been developed to solve these equations together with their boundary and initial conditions. Among these techniques the

finite difference and finite element method are probably the most well-known methods used in order to solve these problems.

MIKE 11 is a software package developed at Danish Hydraulic Institute (DHI) to illustrate the simulation flows, water quality, sediment transport in river estuaries, and saltwater intrusion into river estuaries. It is a dynamic, user friendly 1-dimentional modeling tool for the detailed design, management, and operation of complex or simple rivers and channel systems. MIKE11 could be classified into hydrodynamic module and Advection – Dispersion module as the following:

2.7.1. Hydrodynamic module (HD):

MIKE11 simulates one-dimensional channel flow by solving the fully dynamic Saint- Venant equations, which define the conservations of mass and momentum. Saint-Venant equations are derived on the basis of the following assumptions:

- The water is incompressible and homogeneous without significant variation in density.
- The bottom slope is small.
- The wave lengths are large compared to the water depth. This ensures that the flow everywhere can be regarded as having a direction parallel to the bottom, i.e. vertical acceleration can be neglected and a hydrostatic pressure variation along the vertical can be assumed.
- The flow is sub-critical.

The basic Saint equation which is used in MIKE 11 as the following:

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q_L \qquad \text{(1) Continuity equation}$$

$$\frac{\partial Q}{\partial t} + \frac{\partial\left(\alpha \frac{Q^2}{A}\right)}{\partial x} + gA\frac{\partial h}{\partial x} + \frac{gQ|Q|}{C^2 AR} = 0$$ (2) Momentum equation

Q - Discharge (m^3/s)

A - Cross-sectional area (m^2)

q_L - Source/sink discharge per unit length (m^2/s)

H - Water level (m)

M - Manning's number ($m^{1/3}/s$)

R - Resistance radius (m).

The computational grids are created with alternating Q (discharge) and h (water level) points. The h points are created at the location where cross sectional data are available, and Q points are generated automatically in between the h points. The differential equations are solved using a 6-point Abott-scheme (Quoc Viet Trinh, 2009).

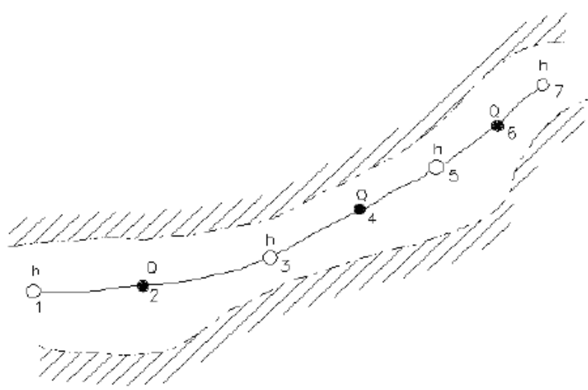


Figure (2-6) channel section with computational grid, 6 Point Abbott-Ionescu Finite Difference Scheme dynamic/diffusive/ kinematic

The transformation of (1) and (2) equations in Saint Venant equation, to a set of finite differences equations, is performed on a computational grid consisting of alternative Q and h points, i.e. points where the discharge Q and water level h are computed at each time step, see figure (2-6). The computational grid is generated automatically by the model

on the basic of the user requirements. Q points are always placed midway between neighboring h points, while the distance between h points may differ. The discharge will be defined as positive in the positive x-direction (increasing chainage) (DHI, 2009).

MIKE11 provides an option where bed resistance (Manning's n) can be calculated as a function of hydraulic parameters such as water depth, hydraulic radius, and flow velocity.

In this study the bed resistance was calculated as a function of the flow velocity according to the following equation (DHI, 2009):

$n = aV^b$ ……… (1)

Where;

n is the Manning roughness coefficient,

a and b are calibration coefficients, and

V is the flow velocity.

2.7.2. Boundary condition:

External boundary conditions are required at all model boundaries, i.e. all upstream and downstream ends of model branches which aren't connected at a junction. The relationships applied at these limits consist of:

- Constant value of h or Q.
- Time varying value of h or Q.
- Relationship between h and Q (rating curve).

2.7.3. Advection-Dispersion module (AD)

The transport of dissolved matter in water basically depends on two phenomena; advection and dispersion. Advection refers to the movement of the dissolved materials at

the current velocity in any direction. Dispersion refers to the process by which these materials are mixed within the water column (DHI, 2009). In this study, the salinity (Electrical Conductivity EC) will be used to determine the transport of the sea water into the Rosetta branch water.

The advection-dispersion (AD) module is based on the one-dimensional equation of conservation of mass of a dissolved or suspended material, i.e. the advection-dispersion equation. The module requires output from the hydrodynamic module, in time and space, in terms of discharge and water level, cross-sectional area and hydraulic radius (DHI, 2009).

The Advection-Dispersion Equation is solved numerically using an implicit finite difference scheme which is, principally, unconditionally stable and has negligible numerical dispersion. A correction term has been introduced in order to reduce the third order truncation error. This correction term makes it possible to simulate advection-dispersion of concentration profiles with steep fronts (DHI, 2009).

The one-dimensional (vertically and laterally integrated) equation for the conservation of mass of a substance in a solution, i.e. the one-dimensional advection-dispersion equation reads:

$$\frac{\partial AC}{\partial t} + \frac{\partial QC}{\partial x} - \frac{\partial}{\partial x}\left(AD\frac{\partial C}{\partial x}\right) = -AKC + C_2 q$$

Where,

C: concentration

D: dispersion coefficient

A: cross-sectional area

K: linear decay coefficient

C_2: source/sink concentration

q: lateral inflow

x: space coordinate

t: time coordinate

The equation reflects two transport mechanisms (DHI, 2009):

3. Advective (or convective) transport with the mean flow;

4. Dispersive transport due to concentrations gradients.

2.8. Previous studies on saltwater intrusion into river estuaries:

There were many studies on different coastal zones regarding Sea Level Rise and the impacts of salt water intrusion into the river estuaries and the surrounding zones.

In Vietnam; there was a study has been carried out on the estuaries Red Rivers, which is considered the biggest fresh water resource in the north of Vietnam, explaining the process of the saltwater intrusion into its estuaries. The dry season lasts 7 months from November to May and during this season the water in the river is provided mainly by ground water, upper catchment water, and 20 % of it from rainfall in dry season. This means that the water flow in the river became low and at the same time the tidal range is high around 4m; that is enhancing the saltwater to invade the Red River estuaries. Number of other reservoirs was built, for the flood mitigation, in order to provide more water to the downstream point during the dry season and for other purposes. These reservoirs will be improved in the near future because the water in the reservoirs affects the increase of the flow downstream of reservoir and helps to provide more water for socio-economic activities as well as controlling saline water intrusion into estuaries.

Salinity concentration along the rivers at different times, water levels, water discharges from upper reservoirs, tidal series, and river cross section data were used as inputs for running and calibration the MIKE 11 model. The results indicated that the distance of saltwater intruded into the river mouth depends on the estuary characteristics, discharges from upper reservoirs and tidal phases (low and high tides) (Vu Minh Cat and Bui Duong 2006).

In France; the delta region of the Rhone River had many impacts because of SLR, i.e. moderate salt intrusion was expected into the Loire estuary, Coastal erosion, lowland flooding, and ground water salinization are the main impacts expected from SLR. There was a study has been conducted on the Loire estuary using a numerical model for evaluating the displacement of the salinity front corresponding to 0.5g/liter by 60cm SLR and river discharge value of 150m^3/S; the result showed that the salt water has intruded to the estuary of the River in the upstream direction by 1km. Other study has clarified that during the last 20 years, the saltwater has been intruded to the estuary till 10km distance towards the upstream (Paskoff, 2004).

In Cavite city, Philippines; there is a gradual increase in Sea level in Manila Bay recorded by the National Mapping and Resource Information Authority (NAMRIA), the data obtained covering the period in the years from 1972 to 2000, which indicates that there is an increase of the Sea Level Rise by 0.90 m over the 29-year period. There were seven case studies reported that there is saltwater intrusion due to SLR and flooding into the groundwater and water systems, and also flooding into the infrastructures causing salinity of the drinking water and rusting of the infrastructures of the water systems. Floods affected 49% of the Cavite city (reported by Cavite City Engineering's Office) due to rise

of the sea level by the tidal action, and coastal erosion where some studies approved that the shore line position changed due to coastal erosion (Sales Jr. 2009).

Morocco as well was not exempted from the impacts of the climate change and sea level rise. Definitely in the Tangier Bay which is considered an important socio-economic place in the north of Morocco, there was a study has been conducted in order to assess the vulnerability and adaptation of the coastal zones to the SLR.

By using GIS-based inundation analysis and erosion modeling approach, the potential physical vulnerability to accelerated sea-level rise was investigated, and the most vulnerable socio-economic sectors were assessed. It was found that 10% and 24% of the area will be at risk of flooding for minimum (4 m) and maximum (11 m) inundation levels respectively.

The most severely impacted sectors are expected to be the port, the urban area, tourist coastal infrastructures, the railway, and the industrial area. Shoreline erosion would affect nearly 20% and 45% of the total beach areas in the years 2050 and 2100 respectively.

In order to face out the Sea Level Rise consequences, the decision makers decided to fix sand dune, beach nourishment, and building of seawalls to protect the urban and industrial areas. As well as upgrading awareness, building regulation and urban growth, planning should be the most appropriate tool to ensure a long-term sustainable development, while addressing the vulnerability of the coast to future sea-level rise impacts. (Maria Snoussi, et al. 2008)

In Egypt, there was a study carried out to show and assess the vulnerability and the expected losses in many sectors and socio-economic impacts of the Sea Level Rise in the Delta Region in the northern part of Egypt, Alexandria and Port Said in particular. The

outcomes of the study on Alexandria governorate indicated that, if there will be no action taken, an area of about 30% of the city will be lost due to land inundation. Almost 2 million people will have to abandon their homeland, moreover, about 195,000 jobs will be lost and an economic loss of over $3.5 Billion is expected over the next century. Regarding Port Said governorate; the outcomes indicated that the beach areas are severely affected which lead to negative impacts on tourism firstly, followed by urban areas. The agriculture sector is the least affected sector. It is estimated that the economic loss is over $ 2.0 Billion for 0.50 m SLR and may exceed $ 4.4 Billion for 1.25 m SLR (El-Raey, Dewidar and El-Hattab, 1999).

After analyzing the suitable adaptation options to overcome the Sea Level Rise and its impacts, it was found that the cost for adaptation is very high and costly. The most cost effective option is the land-use change, however with relatively very high cost measure. It is recommended that an Integrated Coastal Zone Management (ICZM) approach can be adopted since it provides a reasonable tradeoff between costs and cost effectiveness, as ICZM is a dynamic, continuous and iterative process designed to promote sustainable management of coastal zones, (European Commission, 1999)

In Bangladesh, the economic development and livelihood are under the threat of the climate change impacts. Bangladesh has been identified as one of the most vulnerable countries to the impacts of global warming amongst 27 countries as an induced accelerated sea level rise occurs due to its geographical location. A study presents the potential impacts of the sea level rise and salt water intrusion and its consequences uses numerical 2-dimensional and 1-dimensional models named MIKE21 and MIKE11 for simulation. The outcomes of the study indicated that, by 10% increase of rainfall, as is imposed in 2080,

with 62 cm sea level rise 16% more area will be inundated during monsoon. The most vulnerable districts are Bhola, Ptuakhali and Barisal.

From the model results, it was found that in Hatia and Manpura Island in the Meghna Estuary, maximum salinity levels will be increased to 3 ppt and 5 ppt due to 27 cm and 62 cm sea level rise respectively, affecting the fresh water zone in the Gorai River (Md. Mobassarul HASAN, Zahirul Haque Khan, and Upal Mahmud, 2003).

CHAPTER THREE METHODOLOGY

3.1. Introduction

This chapter focuses on three points. The first point is the current situation of the water salinity in Rosetta branch assessed by water sampling from specific points. The second point is the trend analysis of the water salinity variation by special and temporal changes is done. In this part also, finding a relation between the River water discharge, salinity intrusion, and rainfall is discussed. The third point is the MIKE11 model used for simulating water salinity invasion and figuring out to which point the saltwater invades towards the upstream of the Rosetta branch.

3.2. Principal elements for the survey program:

3.2.1. Objective of the monitoring and the target parameters:

The objective behind the water sampling from Rosetta branch is to assess and evaluate the current salinity situation in the branch. In order to know to what extend the sea water intrudes into the Rosetta estuary.

Seawater is highly concentrated with anions (Cl^-, and SO_4^{2-}) and cations (Na^+, Mg^{2+} and Ca^{2+}). Hence, the values of these parameters will act as evidence or indicator leads to know to which extent the water comes from the sea intrudes towards the upstream.

3.2.2. Description of the monitoring area:

Rosetta River Nile Branch represents the main freshwater stream that extends northwards for about 236 km on the western boundary of the Nile Delta from Egypt's Delta Barrage. Rosetta branch has an average width of 180 m and depth from 2 to 4 m. The estuary is delimited by a barrage for controlling water discharge at Idfina City, 30 km

upstream the sea. The following sketch shows a drawing for the two barrages and the seawater and River water flow directions.

Water sampling process started from the most downstream point of the Rosetta branch towards the upstream, to monitor the gradual decrease of the water salinity in the branch as we are directing to the upstream as the research objective is to assess and evaluate the water salinity due to Mediterranean Sea water intrusion into the Rosetta estuary. To do so, assess the water salinity due to sea water intrusion, there is no need to evaluate the salinity for the whole branch but it will be enough to start from the downstream point and take samples as going upstream until the concentration of the monitored parameter starts to vanish or reach to its normal guidelines to comply with the water quality standards.

3.2.3. Water sampling points:

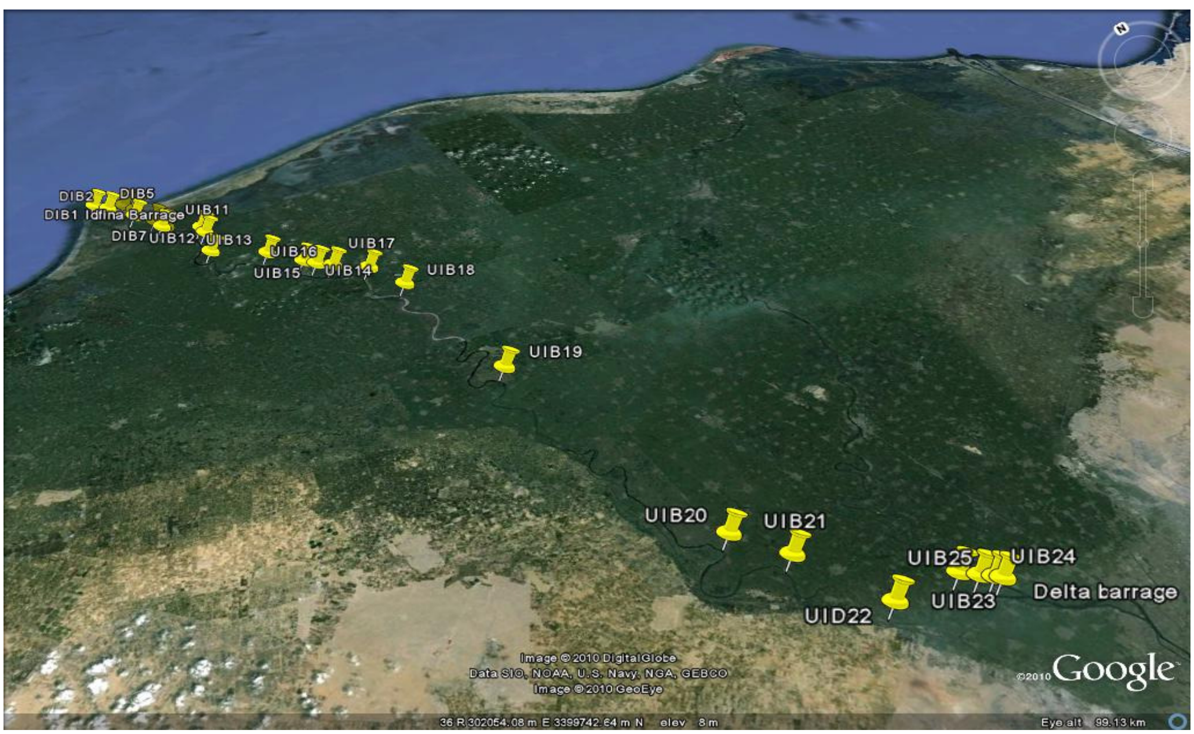


Figure (3-1) the sampling sites along the Rosetta branch and the two barrages.

Twenty six sampling sites, as in figure (3-1), were selected along the Rosetta branch of the River Nile. Nine points after Idfina barrage starting from the meeting point between the Mediterranean Sea and the Rosetta branch. Fifteen sampling points were selected between the two barrages, Idfina and Delta barrages, along the Branch upon the individual or integrated pollution, in order to assess its effects on the water quality to obtain a good grasp of wide range of information. The last point was before bifurcate of the Nile River into its two branches, Rosetta and Damietta, and that is to recognize the water salinity before any impacts on the branch, as a reference point. Selecting “Al Fostat Station” as reference point of the River Nile water quality, for judgment of pollution sources-in accordance with regulations-is related to socio-economic activities that have been an effect on the ambient water.

3.2.4. Field work and water sampling:

There was arrangement with the Cairo Central Center (CCC) Laboratory which follows the Ministry of State for Environmental Affairs (MSEA).

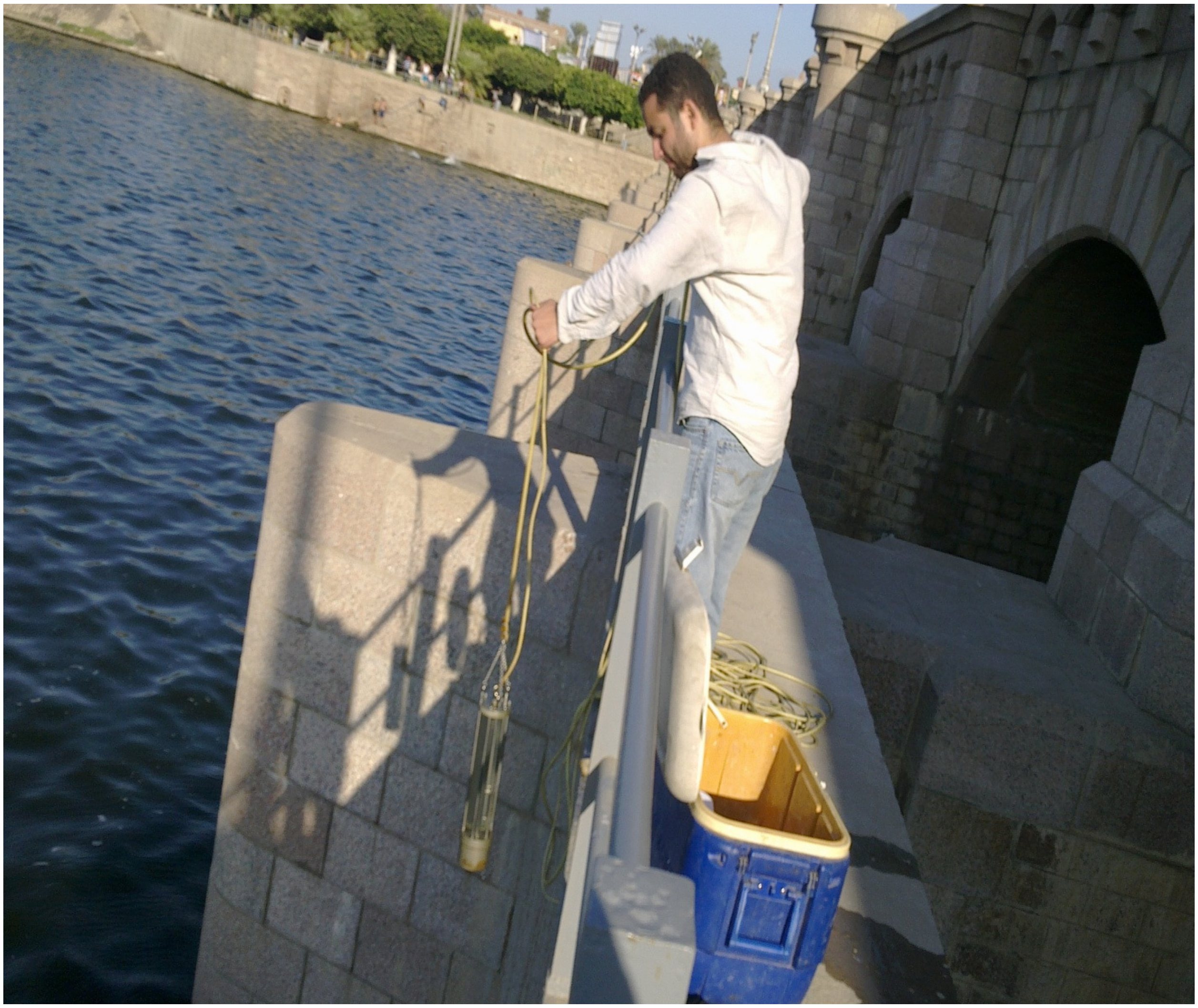


Figure (3-2) Photo during water sampling from the Rosetta branch, Egypt (Downstream the barrage, 2010)

The laboratory received the water samples from the Rosetta branch on (13th of Sep. 2010).

In this present research, all the samples were collected at the central area of the Rosetta branch and at a depth of about 50 cm. Grab samples were collected from each sampling point two liters capacity grab sampler for applying rules of QA/QC system of analytical methods in Cairo Central Center especially after complying with ISO/IEC 17025

requirements and getting Egyptian accreditation council certificate. Preservation of samples and water samples containers achieved according to the Standard Methods for Examination of Water and Wastewater (American Public Health Association 2005, 21st Edition). The main aim for preservation of the water samples and preserving it in the suitable containers with suitable physical conditions is to avoid the chemical interference and the cross contamination of the water samples. The appropriate chemical preservative for each target parameter and the materials of sample's containers in details will referred be to in the Standard Methods for Examination of Water and Wastewater - American Public Health Association (APHA 2005, 21st Edition).

3.2.5. Water samples transportation:

The water samples were transported by a car from the sampling sites beginning from Kafr ElSheikh Governorate in the north along the Rosetta branch to Cairo Governorate in an Ice Box for the water samples. This Ice Box contains buckets of ice to keep the temperature of the water samples as low as possible until reaching Laboratory site in Cairo, and also with preservative chemicals as in the table 1. The sampling points have been reached by boat because the samples must be taken from the middle of the Branch. The sampling process was under a careful supervision and particular attention to sample quality control.

3.2.6. Water samples analysis:

According to Standard Methods for Examination of Water and Wastewater - American Public Health Association (APHA 2005, 21st Edition), the previous parameters have been analyzed. Table (3-1) shows the methods have been used for the water samples analysis.

Table (3-1) the methods have been used in the analysis according to the Standard Methods for Examination of Water and Wastewaters (SMWW) the 21st edition, APHA 2005).

Parameter	Analysis Method
Total Dissolved Solids	2540 C. Total Dissolved Solids Dried at 180°C
Conductivity	2510 B. Electrical Conductivity Method
Sulfate	4110 B. Ion Chromatography with Chemical Suppression of Eluent Conductivity
Chloride	4500-Cl^- B. Argentometric Method
Potassium	3111 B. Direct Air-Acetylene Flame Method
Calcium	3111 B. Direct Air-Acetylene Flame Method
Magnesium	3111 B. Direct Air-Acetylene Flame Method
Sodium	3111 B. Direct Air-Acetylene Flame Method

3.3. Saltwater intrusion modelling in the Rosetta branch

In this study, the widely used one-dimensional modeling package – MIKE11 and MIKE view software (2009) developed by the DHI – was employed for the simulation of the saltwater intrusion. Also, they are used to predict saltwater intrusion for two proposed scenarios namely, 0.5 m and 1.0 m SLR.

3.3.1 Data collection from the secondary sources:

Intentionally to be able to set up the model there are a lot of data must be available, not only for running the model, but also for calibration and validation the model results. The following data were used to achieve so:

- *Hydrological data:*

The hydrological data includes the water discharge of the Nile River at the upstream of the study area and also at specific regions along the Rosetta branch, and water level at the downstream of the Rosetta branch, and also at specific points for calibration. More over Mediterranean Sea water level records. These data are for the years of 2008 and 2009.

- *Hydraulic data:*

The hydraulic data for the study area are the cross sections for the branch which are required for model setup. A total of 232 cross section points were selected along the Rosetta branch with 1Km intervals.

- *Water salinity (Electrical Conductivity):*

EC data for the year 2009 are for the upstream boundary, downstream boundary, and at the middle of the study area at Chainage 1020000. The frequency of the data is monthly.

These data was obtained from different places, Ministry of Water Resources and Irrigation (MWRI), Ministry of States for Environmental Affairs (MSEA), Nile Research Institute (NRI), and Environment and Climate changes Research Institute (ECRI) under National Water Research Center (NWRC).

3.3.2. MIKE 11 model set up:

MIKE11 offers different modules for modeling flows, sediment transport, water quality in estuaries, rivers, channels, irrigational networks and similar water bodies. In this research, two modules were used, namely the Hydrodynamic module (HD) and Advection Dispersion modules (AD) beside other file editors which are as Network file editor, Cross Section editor, and boundary file editor as following:

3.3.2.1. Boundary conditions:

In this editor file the boundary conditions for the study area were specified at upstream and downstream ends of the river network. A time series files of measured water discharge was used as an upstream discharge boundary condition for Rosetta branch and Electrical Conductivity (EC) values for the upstream water during the year 2009. Seawater level measurements were used as a downstream boundary condition and also the EC values at the downstream of the branch where it discharging its effluent to the Mediterranean Sea during the same time of simulation. Figure (3-3) in the appendix shows the boundary conditions in the MIKE11 for the study area.

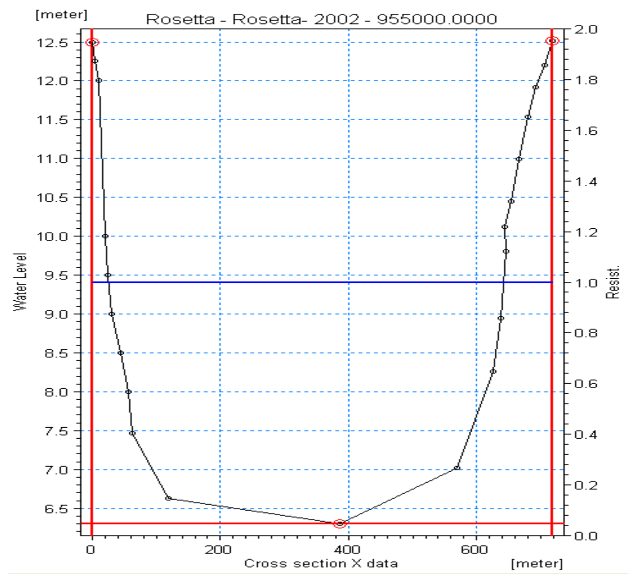
3.3.2.2. Network file editor:

The Rosetta branch network is included in the model set up of the year 2009. The length of the study area which is incorporated in the model is about 223 Km. The alignment of the Rosetta branch network was created by digitizing a satellite map from Google Earth

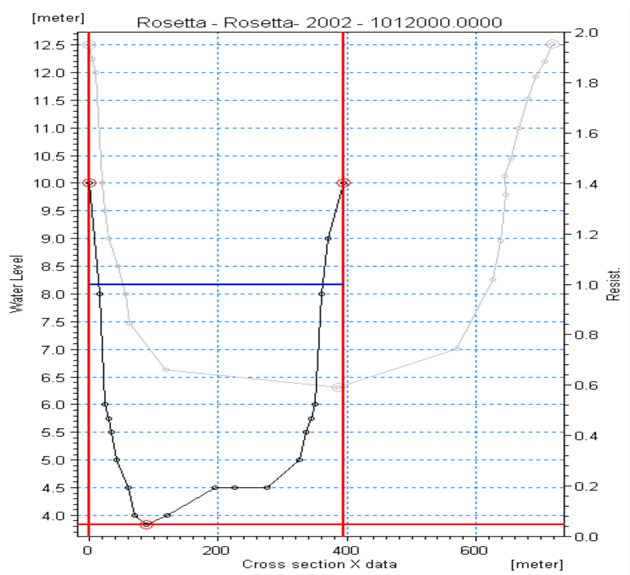
2010 for the Rosetta branch as a background map in order to draw the Branch network. During drawing the branch network, one control structure was taking into account that there is one water infrastructure and they were inserted in the branch network as shown in the figure (3-4) in the appendix A.

3.3.2.3. Cross Section file editor:

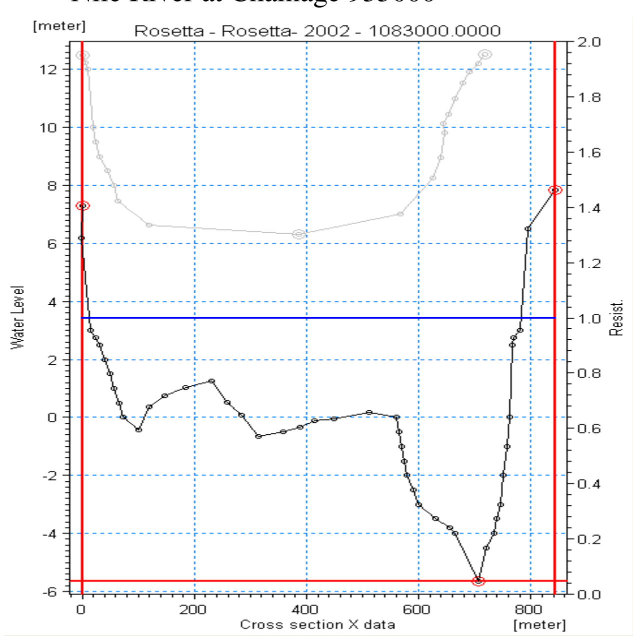
The available Cross-Sections are around 232 were measured for the year 2002.

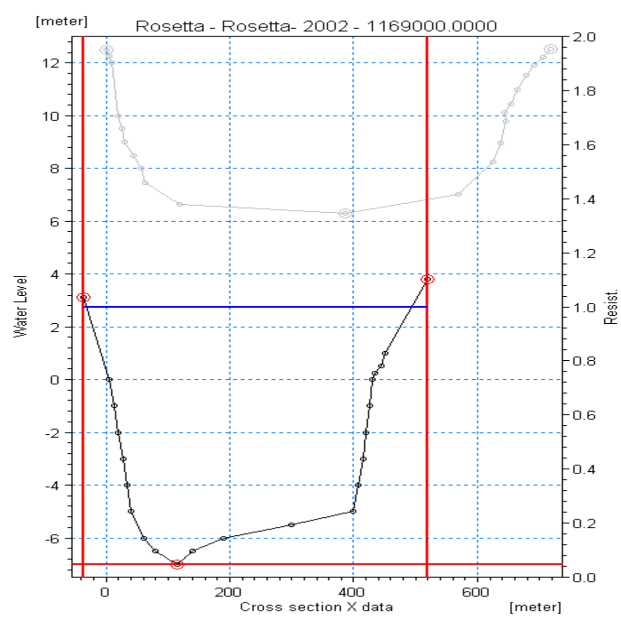


Cross section of Rosetta
Nile River at Chainage 955000



cross section of Rosetta branch,
Nile River at Chainage 1012000





Cross section of Rosetta branch, Nile River at Chainage 1083000

Cross section of Rosetta branch, Nile River at Chainage 1169000

Figure (3-5) some cross sections in simulation network

The Cross-sections are specified by a number of x-z coordinates where x is the transverse distance from a fixed point (often left bank top) and z is the corresponding bed elevation of the Nile River branch. The hydrodynamic module was setup by entering every cross section at given chainage for Rosetta branch with 1-2 Km interval between each cross section.

3.3.2.4. Initial conditions

The initial conditions of MIKE 11for Rosetta branch were specified by the author in the hydrodynamic and advection dispersion modules. Water level, water discharge, and electrical conductivity values – measured values – were inserted in the model in order to be a start points during the simulation period. The initial conditions of the for the water electrical conductivity values were inserted in the advection dispersion editor file and water level and discharge were inserted in the hydrodynamic editor file. Figures (3-6) and (3-7) show the initial conditions for HD and AD modules respectively. Moreover, the initial conditions in the Simulation Editor under the Simulation tab as shown in figure (3-8).

3.3.3. Running the model:

In order to develop a numerically stable MIKE 11 run capable of using a reasonable time step, some cross sections were adjusted. In all cases, restraint was applied in making modifications to the cross section data so that the MIKE 11 river system would capture the essential flow dynamics of the river system. A stand-alone MIKE 11 simulation with a time step of 1 minute was run for one year period (2009) to fill up the river system with water. Subsequently, MIKE 11 simulations were carried out using a time step of 5 minutes where

the initial conditions of MIKE 11 HD of Rosetta branch were specified in the Simulation Editor under the Simulation tab. After preparing all the previous mentioned editor files and entering it as inputs, it will be easy to start running the model.

3.3.4. MIKE 11 calibration and validation

The model was calibrated by using the field data of daily water discharge and water level and the available data at the water infrastructure downstream for the year 2009. The goal was to fine tune the model parameter until the model reproduce the measurements within a certain degree of tolerance. The spatially varied bed roughness, represented by Manning's (n), was the main calibration parameter. It should be noted that the bed roughness factor was allowed to change according to flow velocity. Coefficients "a" and "b", as described in the Equation (1), were used to calculate bed resistance at different portions of the Rosetta branch. The coefficient "a" was found to typically range from 0.023 to 0.033, and the value of "b" was in the range of –0.05 to –0.35. These coefficients were defined in order to calculate the Manning's (n). Based on these values, the model interpolates the roughness at intermediate locations.

Comparison between the observed and computed discharges and water levels were carried out at three different locations along the Rosetta branch at (976000, 1020000, and 1120000 Chainages*). With the calibrated parameters, the 1-D model was validated with the field data of 2008. In order to quantitatively assess the accuracy of the MIKE11 model, the Root Mean Square Errors (RMSEs) between the modeled and measured values of water levels and salinities were computed.

3.3.5. Sea Level Rise future scenarios:

MIKE11 model was run also for two future scenarios, the scenarios derived from the increase of the global average of the seawater which is the reason to study intrusion of the Mediterranean Sea on Rosetta branch. The same previous steps have been done but with adding to the existing seawater level in the downstream boundary once 0.5 m and then 1.0 m.

* Chainage is the point at which the Cross section is entered. So, every cross section has a specific number

CHAPTER FOUR RESULTS AND DISCUSSION

4.1. Water sampling results:

Water samples have been taken along the Rosetta branch in order to assess the current water salinity. The results of the analysis were as shown in the Table (4-1).

Table (4-1) the results (mg/L) of the anions and cations of the water samples from the Rosetta branch during the closure of Idfina Barrage.

Code	Location by km	EC (µS/cm)	TDS (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	Mg^{2+} (mg/L)	Ca^{2+} (mg/L)	Na^+ (mg/L)
DIB1	0.70 Km from the mouth River (downstream)	44,310	27,794	17,539	7,645	994.5	137.3	11,95[illegible]
DIB2	3.70 Km from the mouth River (downstream)	40,730	26,322	17,067	7,140	822.5	136.4	9,580
DIB3	6.25 Km from the mouth River (downstream)	25,380	15,770	10,255	3,541	518.5	62.5	7,815
DIB4	9.10 Km from the mouth River (downstream)	20,620	13,126	9,713	3,498	375.6	68.8	6,815
DIB5	11.29 Km from the mouth River (downstream)	11,750	7,416	4,243	2,168	248.5	67.2	5,665
DIB6	17.27 Km from the mouth River (downstream)	7,810	5,040	3,206	954	207.7	67.2	2,050
DIB7	19.89 Km from the mouth River (downstream)	6,970	4,524	2,876	901	164.7	65.6	1,931
DIB8	20.81 Km from the mouth River (downstream)	4,400	2,826	236	34	12.6	64	472
DIB9	29 Km from the mouth River (downstream)	4,300	2,626	113	31	22.08	59.2	238
UIB10	29 Km from the mouth River (upstream)	2,345	1,826	82	29	20.16	57.6	138
UIB11	2.04Km from Idfina Barrage (upstream)	1,000	510	62	31	17.28	57.6	67.3
UIB12	9.80 Km from Idfina Barrage (upstream)	904	487	38	20	16.32	57.6	37.3
UIB13	22.72 Km from Idfina Barrage (upstream)	770	402	32	19	16.32	57.6	37.3
UIB14	29.6 Km from Idfina Barrage (upstream)	767	372	38	20	17.28	56	37.3
UIB15	31.92 Km from Idfina Barrage (upstream)	703	368	40	21	19.2	56	37
UIB16	34.72 Km from Idfina Barrage (upstream)	530	268	40	21	19.2	52.8	37
UIB17	40.56 Km from Idfina Barrage (upstream)	505	284	46	24	20.16	51.1	37
UIB18	49.72 Km from Idfina Barrage (upstream)	600	388	44	25	20.16	44.77	37
UIB19	120.94 Km from Delta Barrage (downstream)	922	520	48	25	19.2	36.3	47
UIB20	75.95 Km from Delta Barrage (downstream)	951	536	38	20	16.32	30.5	47
UIB21	31.71 Km from Delta Barrage (downstream)	690	338	34	21	14.4	22	37
UIB22	15.45 Km from Delta Barrage (downstream)	971	500	40	19	19.2	34.4	41.2
UIB23	4.79 Km from Delta Barrage (downstream)	563	300	32	23	17.28	34.4	36.2
UIB24	2.47 Km from Delta Barrage (downstream)	577	302	32	22	20.16	38	36.1
UIB25	0.82 Km from Delta Barrage (downstream)	580	366	38	19	17.28	36	36

REF26	Cairo Reference point	473	272	38.39	78	15.42	20.77	36
The limits in the Law		---	<500	---	<200	---	---	---

It is obvious from the results that some of the parameters that are having a limit in the Egyptian guidelines are exceeding the limits of the Decree No. 402 for the year 2009 concerning the modification of the executive regulations of the law no. 48 for the year 1982 concerning the protection of River Nile and its estuaries from pollution (the exceeding results of the limits are notified by filling grey color). The exceeding limits along the branch because of the Drains that were indicated in the chapter of the introduction. There is a gradient in the concentration of Cations and Anions starting from the (DIB1) to (UIB12) then the concentrations of the Ions increase and decrease depending on the position of the sampling site to the Drains.

The high pollutant concentration exists where the sampling site is close to the Drains.

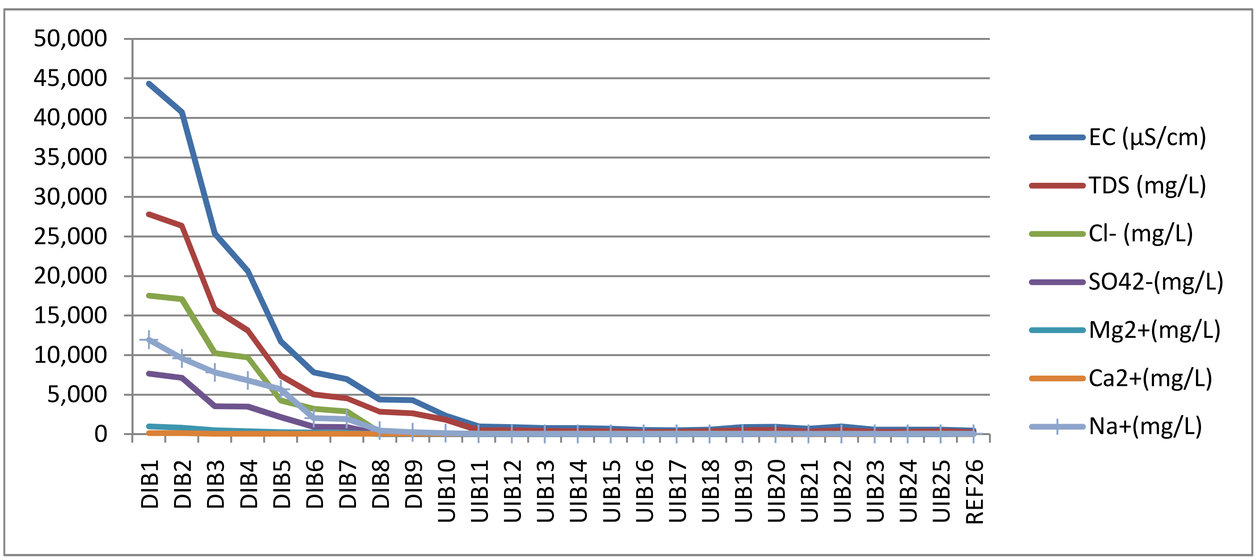


Table (4-2) shows the position of each Drain.

Figure (4-1) the results of the water samples have been taken from Rosetta branch Sep. 2010.

In the Figure (4-1) it is clear that the whole monitored parameters are highly concentrated at the river mouth – Rosetta estuary – and then starts to decrease towards the

upstream. At site UIB10 – Directly upstream the barrage of Idfina- the concentration of Cations and Anions are very high compared with the rest upstream sites.

Table (4-2) the main pollution sources on the Rosetta branch (Marwa Ali, 2007)

Drain	Location Km away from Delta barrage	Description
El Rahawy Drain	9.85	Mixed from agricultural & Industrial effluent
Sabal Drain	74	Agricultural Excess Water
El Tahrir Drain	85.5	Agricultural Excess Water
Tala Drain	119.4	Agricultural Excess Water

For instance, the Cations and Anions are highly concentrated at the site UIB22, which is close to El Rahawy Drain. The wastewater which is discharged from this Drain is a mixture between agricultural and industrial wastewater. Sampling site UIB19 also close to Tala Drain where highly polluted water there as shown in the Table (4-1). Likewise, site UIB20 which is close to the Sabal Drain records high readings of EC.

4.2. MIKE 11 model Results

4.2.1. Calibration results:

In order to get reliable results from the model, it should be calibrated and the modeled or computed results or values must be very close to the measured ones. To achieve so, comparison has been done at certain Chainages between the computed results – results of the model – and the measured data in the reality to see if there is matching between both results or not. The calibration for four points has been done. The figures from (4-2) to (4-7) show the results of calibration for the water level and water discharge.

In the case of water levels, as downstream boundary condition, is presented in Figures (4-2), (4-4), and (4-6). The results of calibration of the computed with the observed daily water level at specified Chainages are showing a good agreement. Likewise, Figures (4-3), (4-5), and (4-7) show that there is good agreement between the measured and simulated discharge, upstream boundary condition, at the same Chainages.

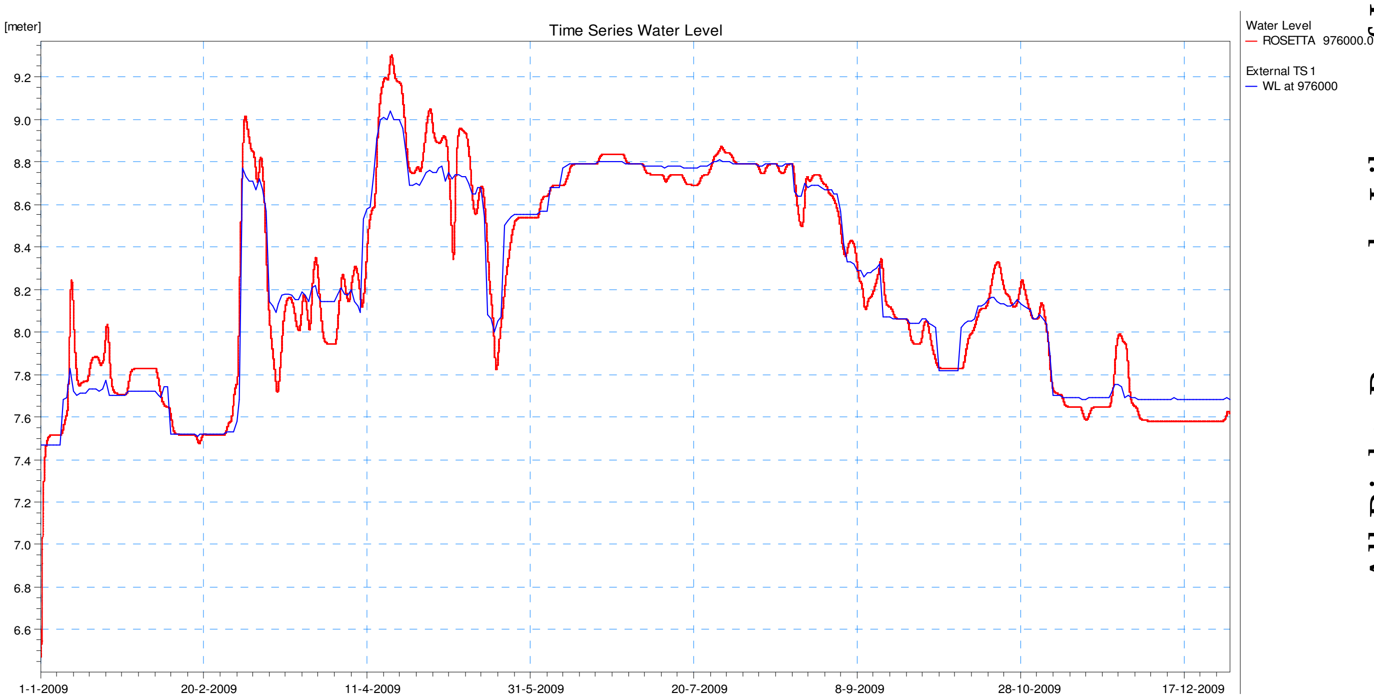
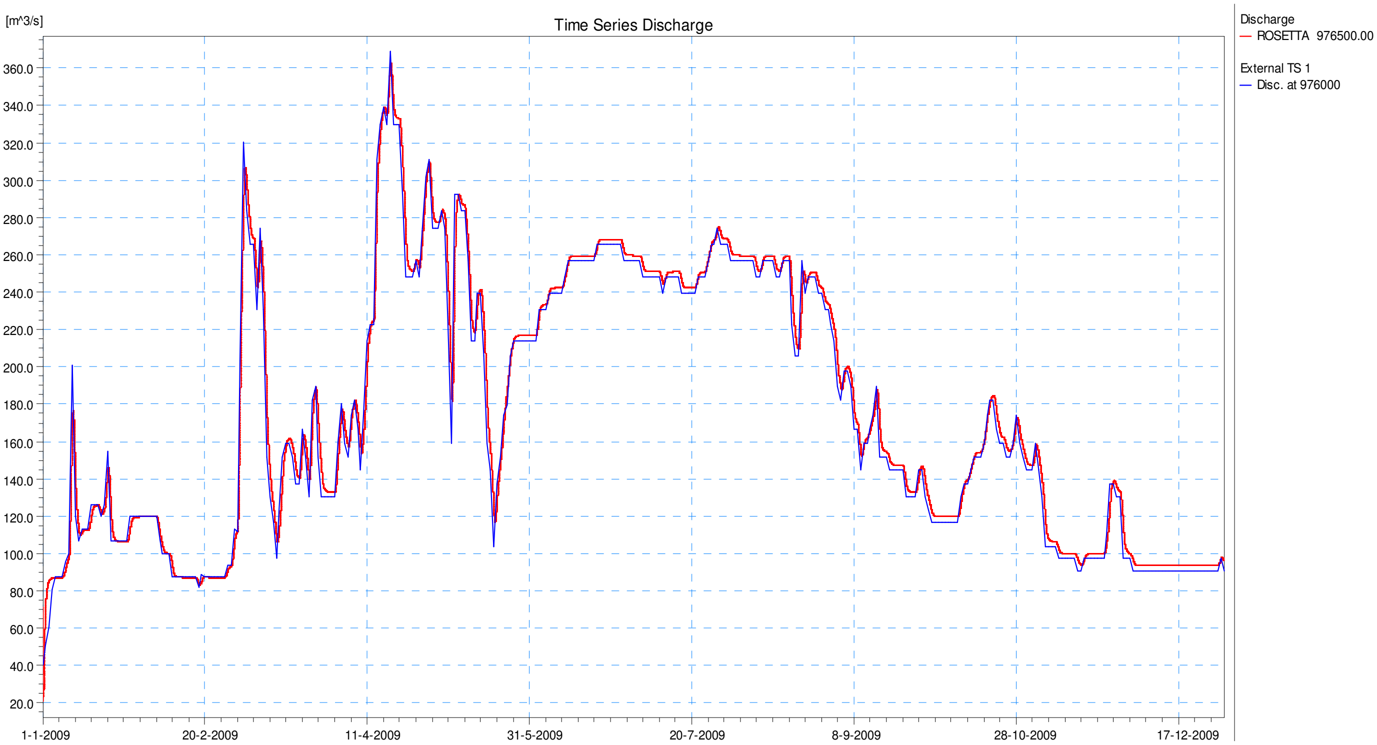


Figure (4-2) observed (blue) and simulated (red) water level at the Chainage 976000 for Rosetta



branch.

Figure (4-3) observed (blue) and simulated (red) water discharge at Chainage 976000 Rosetta branch.

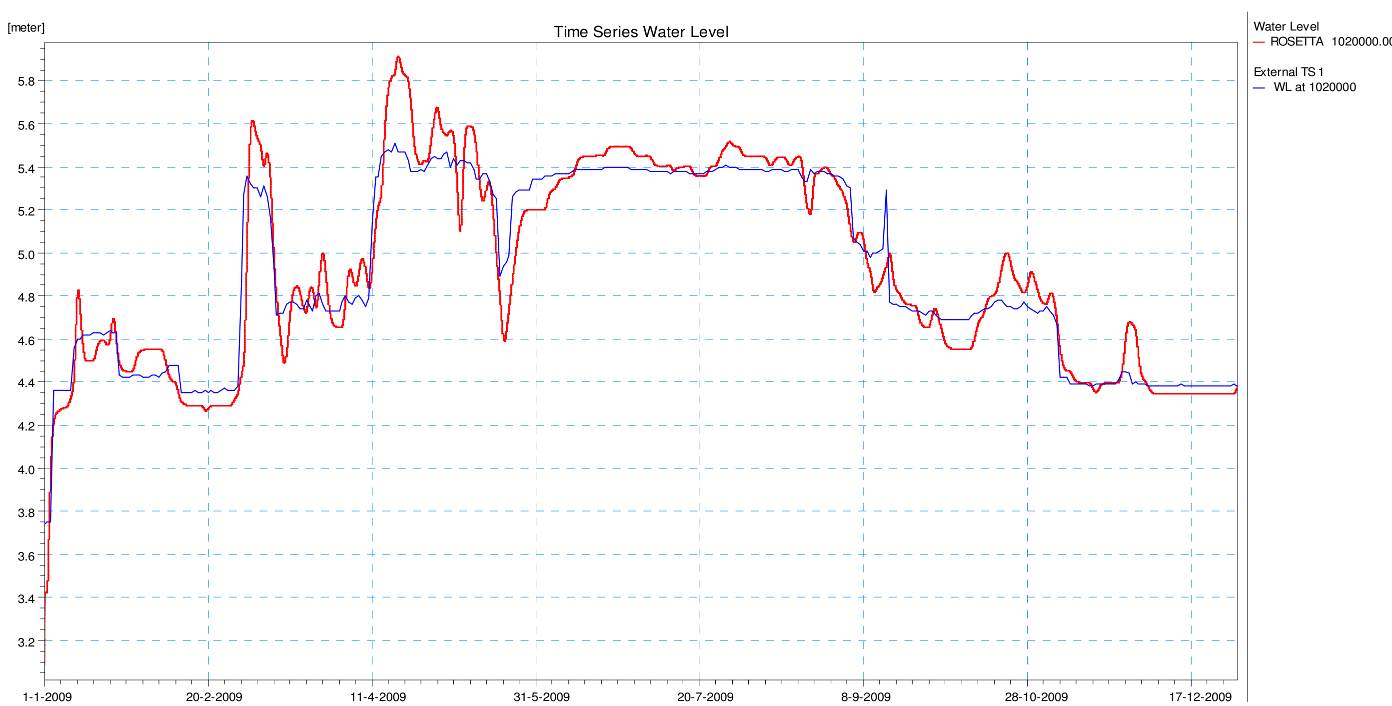


Figure (4-4) observed (blue) and simulated (red) water level at the Chainage 1020000 for the Rosetta branch.

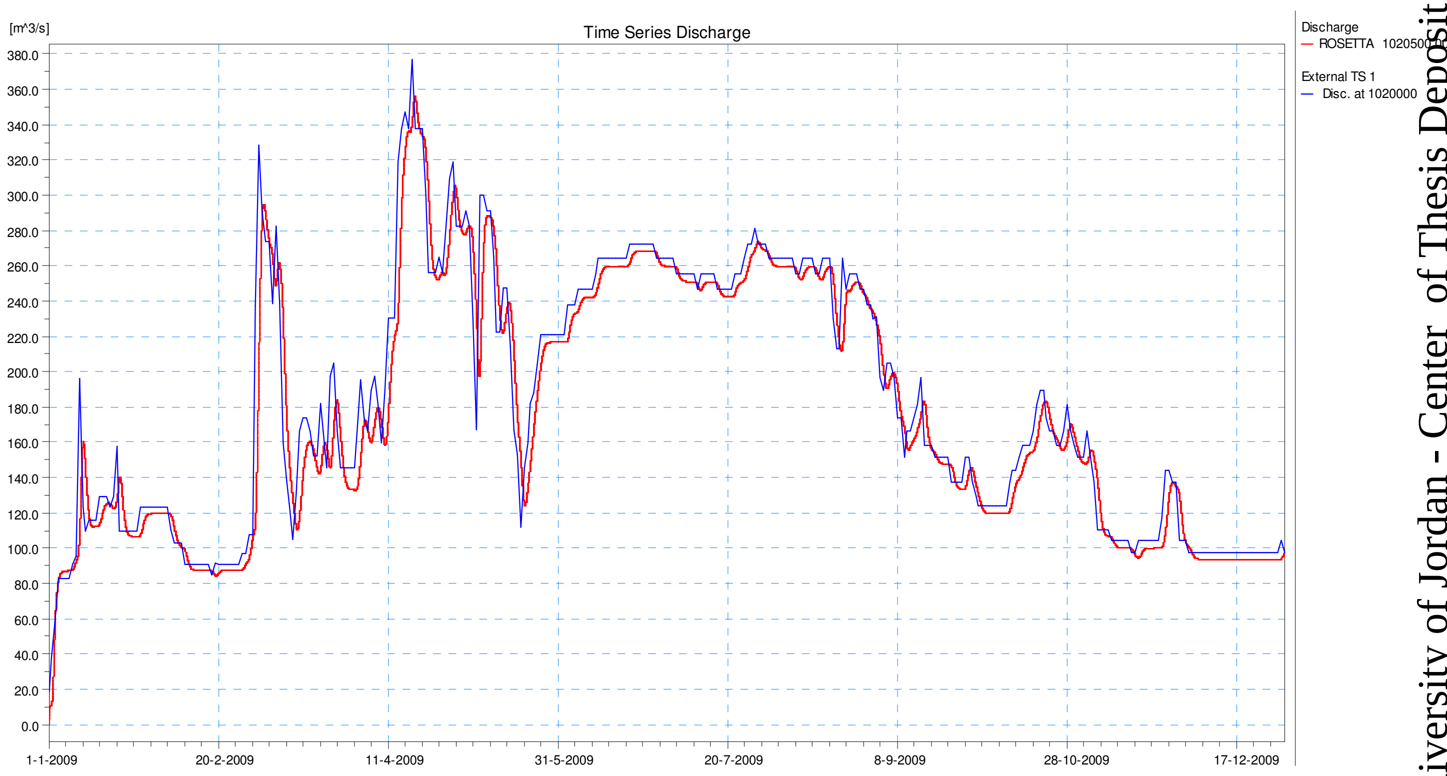


Figure (4-5) observed (blue) and simulated (red) water discharge at the Chainage 1020000 for the Rosetta branch.

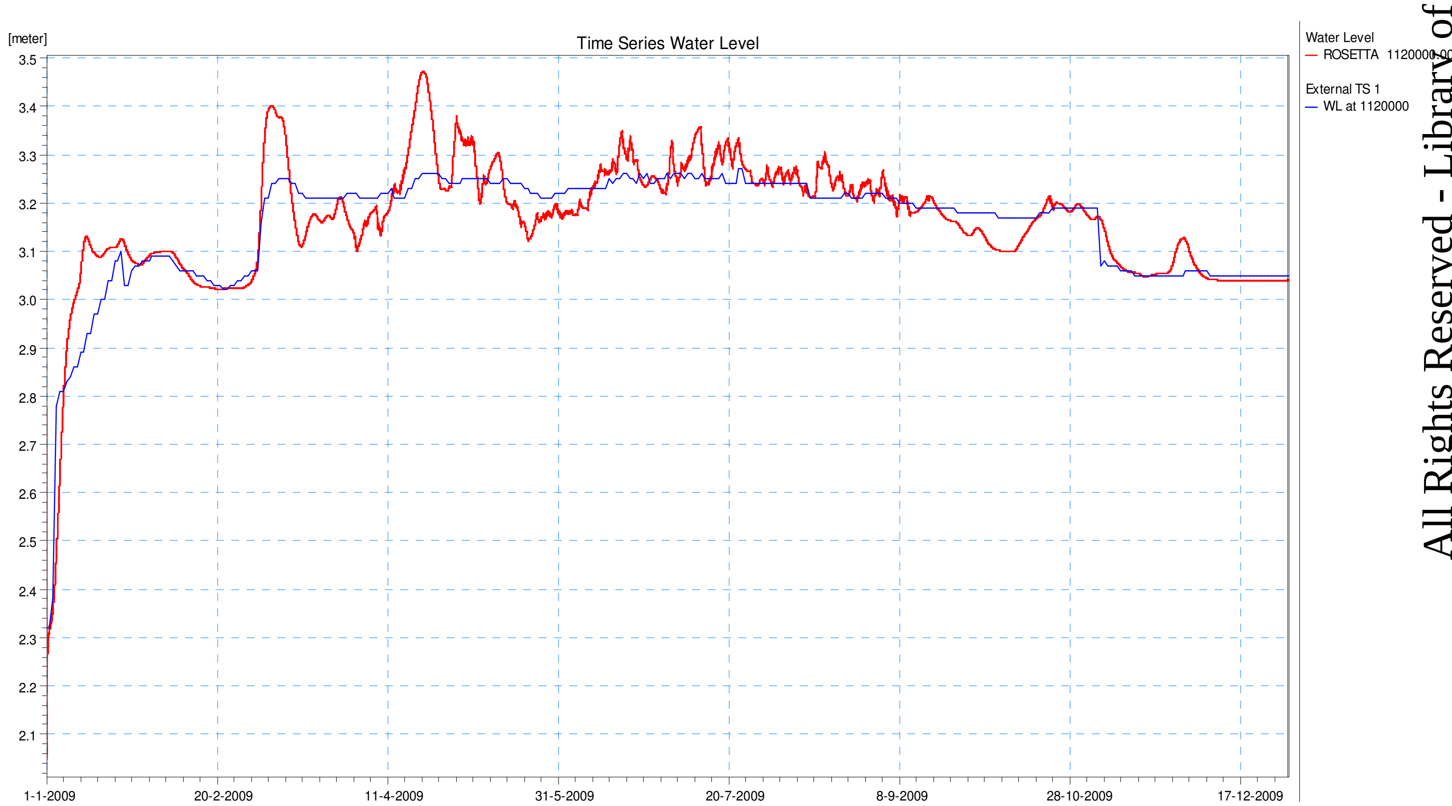


Figure (4-6) observed (blue) and simulated (red) water level at the Chainage 1120000 for the Rosetta branch.

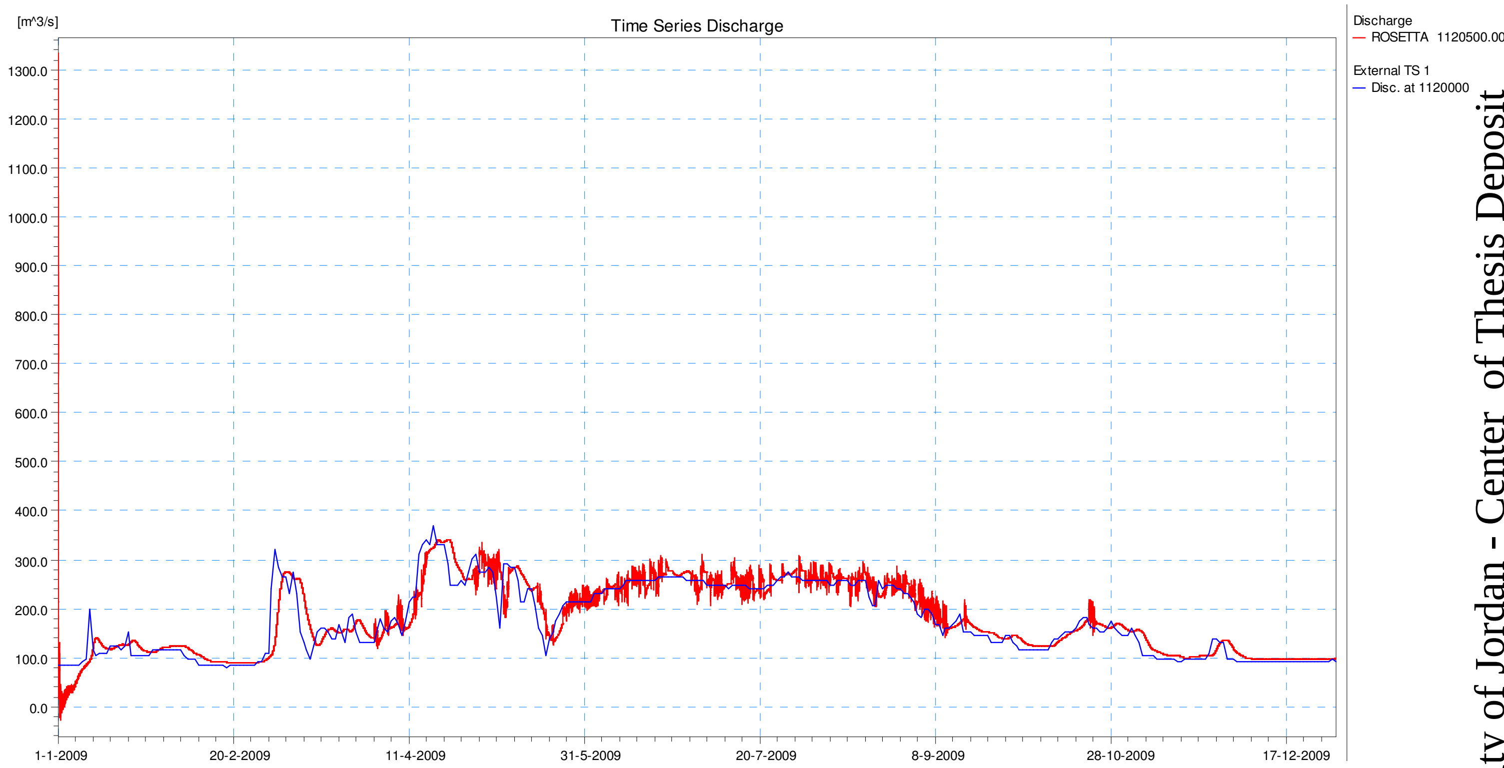


Figure (4-7) observed (blue) and simulated (red) water discharge at the Chainage 1120000 for the Rosetta branch.

It can be inferred from the results that the 1-D model MIKE 11 model is well calibrated for simulating flow and water level in the Rosetta branch.

The results of water salinity calibration show agreement between the computed and the measured data. Figures (4-8) and (4-9) indicate that, the model is reliable. Likewise, the results of the water salinity for the year 2008 show good agreement between the simulated and measured data as shown in figure (4-10).

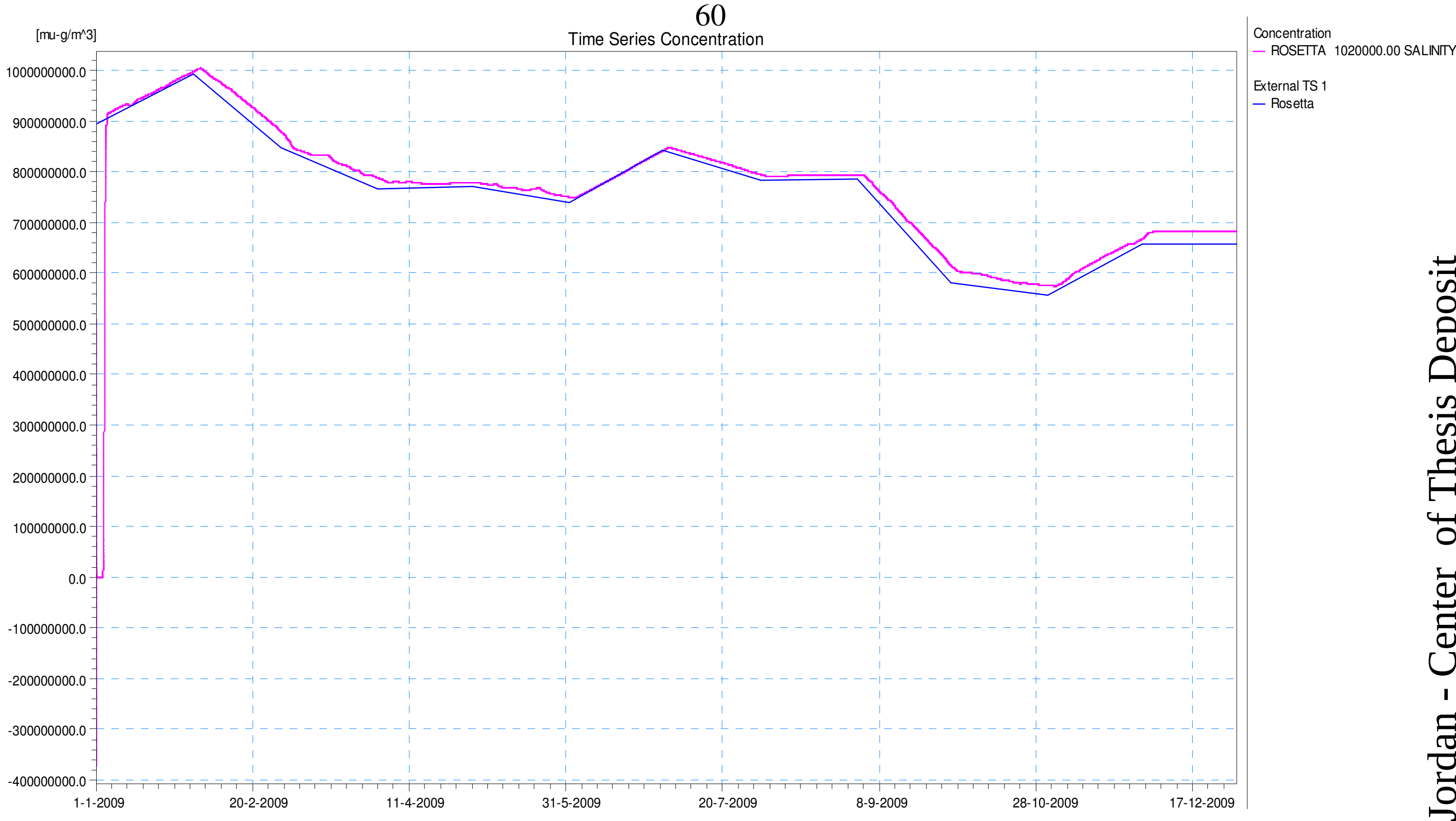


Figure (4-8) observed (blue) and simulated (red) water Electrical Conductivity at the Chainage 1020000 for the Rosetta branch.

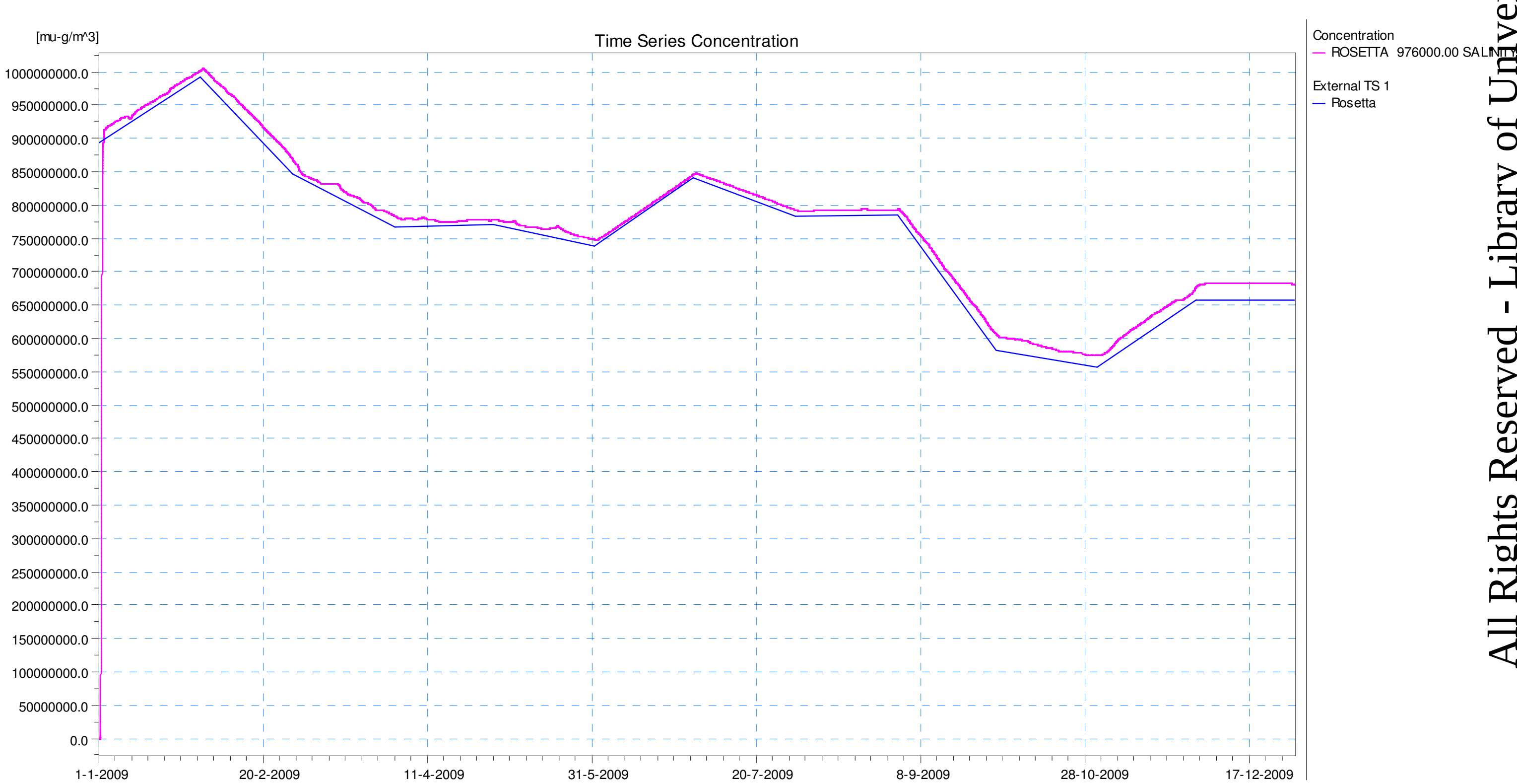


Figure (4-9) observed (blue) and simulated (red) water Electrical Conductivity at the Chainage 967000 for the Rosetta branch.

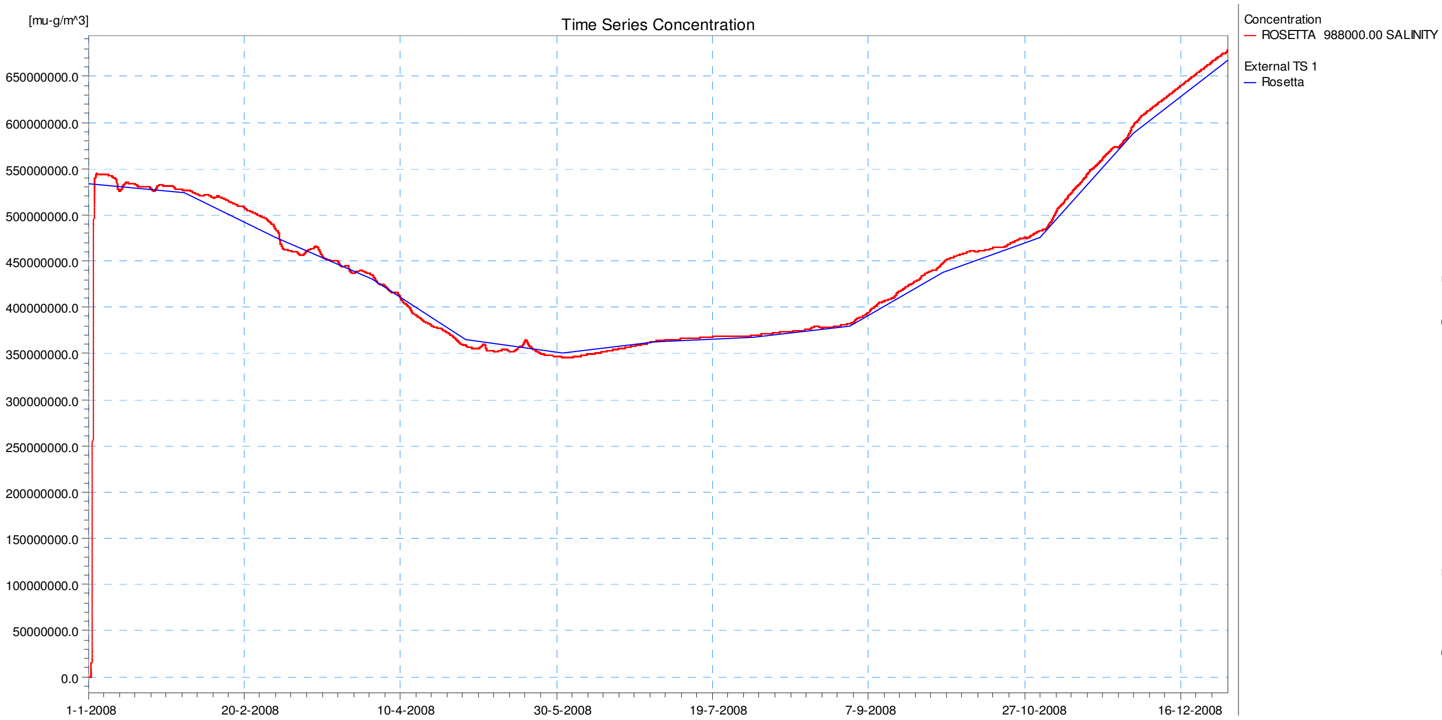


Figure (4-10) Results of validation of water EC for the year 2008 at Chainage 988000. Simulated (red) measured (blue).

Nash–Sutcliffe efficiencies can also be used to quantitatively describe the accuracy of model outputs of discharge. Essentially, the closer the model efficiency is to one, the more accurate the model is (Nash, J. E. and J. V. Sutcliffe, 1970). The following equation was used do insure that agreement between the measured and simulated results:

$$E = 1 - \frac{\sum_{t=1}^{T}\left(Q_o^t - Q_m^t\right)^2}{\sum_{t=1}^{T}\left(Q_o^t - \overline{Q_o}\right)^2}$$

Where;

E is efficiency coefficient, Q_o is observed discharge, and Q_m is modeled discharge. Q_o^t is observed discharge at time *t.* table (4-5) shows the results of the agreement.

Table (4-3) the accuracy of the model results (NASH)

Chainage	976000	1020000	1120000
Average discharge	175.988	182.156	1075.25

NASH	84%	81%	77%

4.2.2. Analysis of Model Parametric Uncertainty

There are some uncertainties affecting hydraulic and hydrological models, these uncertainties could be classified as the following:

a) Uncertainties in input data that drive the model,

b) Uncertainties in data used for calibration,

c) Uncertainties in model parameters, and

d) Uncertainties related to model structure and formulation.

The last two sources of uncertainties are caused by imperfect representation by the model of the physical processes of interest and by the lack of accurate information about the model parameters used to simulate these processes.

Amongst the most important parameters in developing hydrodynamic modes are bed roughness coefficients. Although such coefficients are linked to physical properties of the modeled river reach, their values have to be determined through a calibration process. In general, the aim of the calibration process is to reduce uncertainties in estimating the model parameters while taking into consideration uncertainties in the data used to drive the model and in the ability of the model to accurately represent the physical processes of interest (Ehab Meselhe et.al, 2005)

Another source of uncertainty originates from the lack of field information on how to represent spatial and temporal variations in the bed roughness parameters. The optimization criterion was selected in such a way to minimize differences between the model predictions and the corresponding observations at six intermediate water level

stations and one discharge station. This was quantified by the root mean of squares of differences (RMSD) between observations and model results.

4.2.3. The results of seawater intrusion towards the upstream

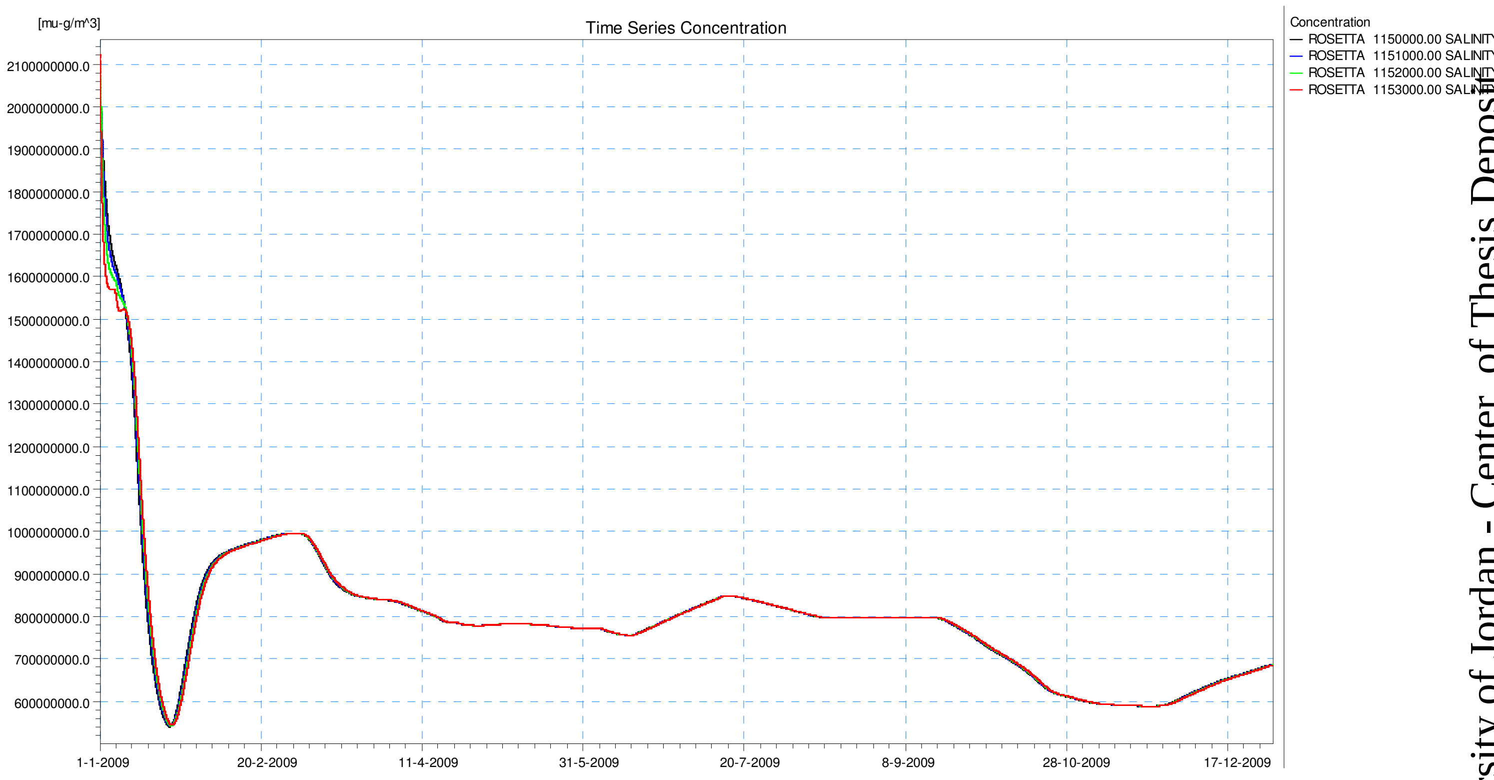


Figure (4-11) the EC gradient intrusion towards the upstream the barrage of Idfina of the Rosetta branch 2009.

The critical point within the branch, at which the seawater could be able to intrude, is the Idfina barrage which is considered as obstacle in front of the invasion of the Mediterranean Sea water. So, the starting point for traceability of the salinity concentration was from this barrage then towards the upstream direction. The model's results came up with that, the water Electrical Conductivity directly upstream the Control structure – Idfina barrage - is around 1900 µs/cm during January and is ranging from 600 to 1000 µs/cm for the rest of the year at the same point as shown in the figure (4-11). Then by going towards the upstream the water EC starts to decrease to its normal concentration from 500 to 800µs/cm. the salty water invades towards the upstream by around 2 Km.

As previously mentioned, there are two assumptions; the high water salinity at the upstream of the barrage of Idfina could be either from the Drains or from the seawater. The data of water discharge through Idfina barrage indicates that, the barrage was opening during January Moreover, the water level data upstream and downstream of the barrage during its opening were approximately at the same level. It means that, the salty water comes towards the upstream during the barrage opening causing the high EC as shown in the figure (4-9).

4.2.4. The projected SLR future scenarios

Based on the same simulation conditions for the year 2009 in terms of the boundary conditions, the water level and discharge, the simulation for the two future SLR scenarios were simulated for 2050 for 0.5 m and 2100 for 1.0 m SLR.

The researches came up by the help of the model that, the saltwater will not affect upstream of the Idfina barrage in case of the closure of the barrage within the two SLR scenarios. Whilst during the opening of the barrages, the salty seawater easily can intrude towards the upstream. In case 0.5 m SLR scenario the seawater will penetrate until around 10 kms towards the upstream and for 1.0 m SLR scenario the seawater will intrude till around 13 kms upstream the barrage. Figures (4-12) and (4-13) show the gradient of salinity invasion.

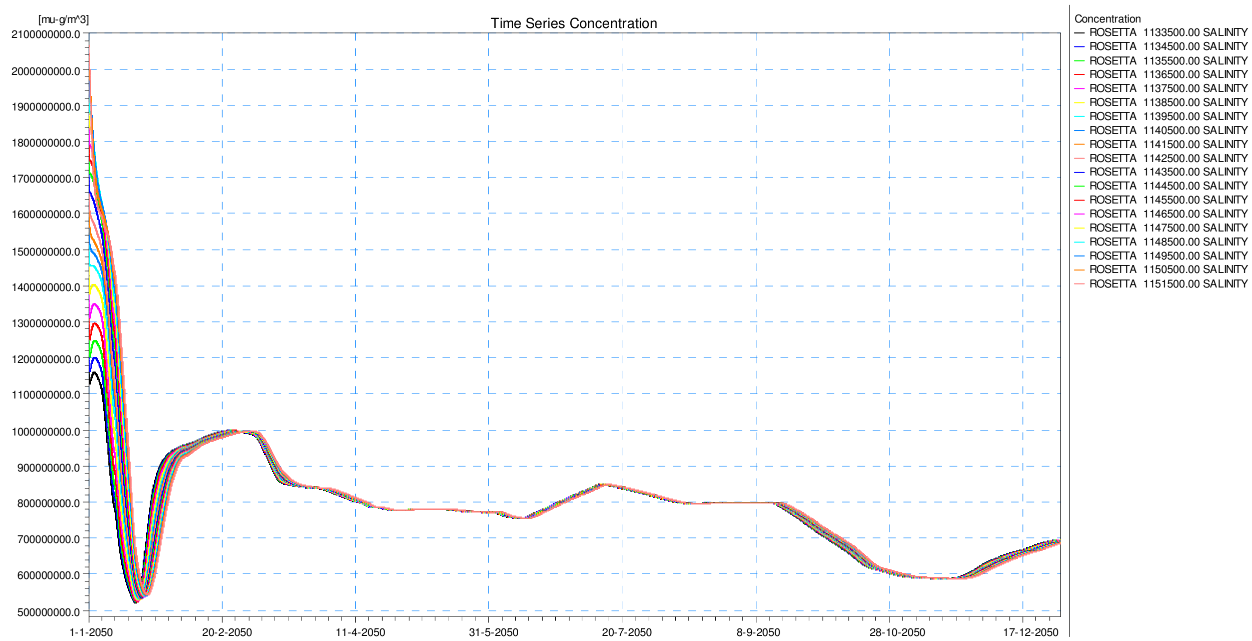


Figure (4-12) the EC simulated intrusion towards the upstream of Idfina barrage for the year 2050, 0.5 m SLR scenario.

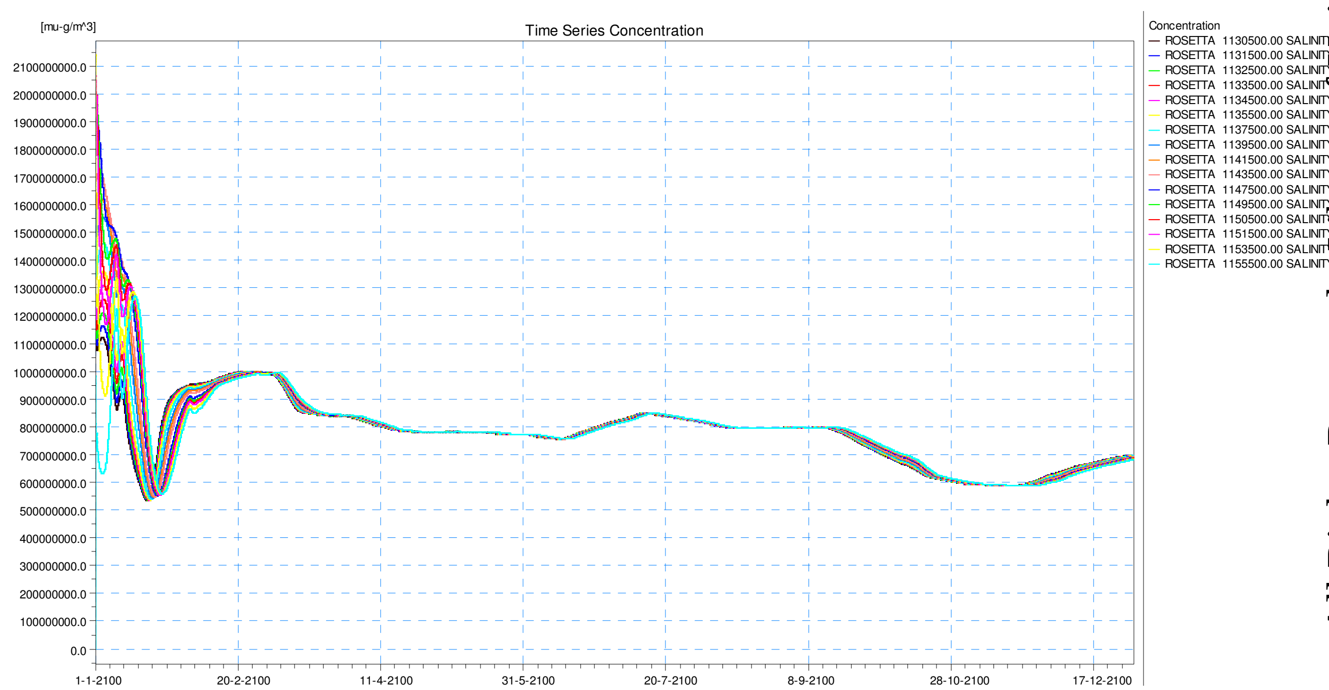


Figure (4-13) the EC simulated intrusion towards the upstream of Idfina barrage for the year 2100, 1m SLR scenario.

MIKE11 model was simulated for the two future scenarios by considering the water discharge as the upstream boundary will be the same in the future. But it is by population increasing and the expected water resources future scarcity, the seawater will be able to intrude towards the upstream even the barrages are closed because the Rosetta branch water level and discharge will be much lower than before.

4.3. Exploratory Electrical Conductivity data analysis:

In this part, the researcher is going to follow up the trend of the water salinity in the area of interest. The data were used in order to interpret the EC concentration which is changing temporally and spatially; EC values from 2004 till 2009 also the data of the water discharge coming from the upstream of the study area, and rainfall data close to the study area. There are three hypotheses could be the main reasons behind the increase in the water salinity upstream of the Idfina barrage as follows:

a) Decreasing of water discharge coming upstream towards downstream direction, and on the other hand, the water coming from the upstream in order to feed the downstream area of the Rosetta branch is sagged and that makes the Mediterranean Sea water invades and intrudes upstream Rosetta branch causing severe increase in the fresh water salinity in the branch.

b) The drainage of the wastewater comes from the main Drains along the Rosetta branch as mentioned before in the (introduction chapter under the title; Sources of pollution on the Rosetta Branch). The water of these Drains contains relatively high concentrations of dissolved salts which cause increasing in the Electrical Conductivity measurements. These dissolved salts go with the water from the upstream towards the downstream where it accumulates there.

c) The last hypothesis is that the Seawater is the main reason behind salinization of the fresh water in the Rosetta branch.

Afterwards, it would be easy to interpret after getting the results from the model, the water samples results, and the results from water salinity trend analysis.

For the year 2009, there was a relation established between the salinity concentration in the Rosetta branch and the water discharge coming from the upstream. These data are for five sites as shown in the figure (4-14).



Figure (4-14) the position of the five sites used for interpretation of the salinity in Rosetta branch.

After establishing the relation between previously mentioned variables, the following figures resulted:

Starting with site number (1), which is the most downstream one as shown in the figure (4-14), for the year 2009, the relation between the salinity values is inversely proportional to the water discharge. Figure (4-15) shows the salinity trend along the year and figure (4-16) shows the water discharge seasonal variation.

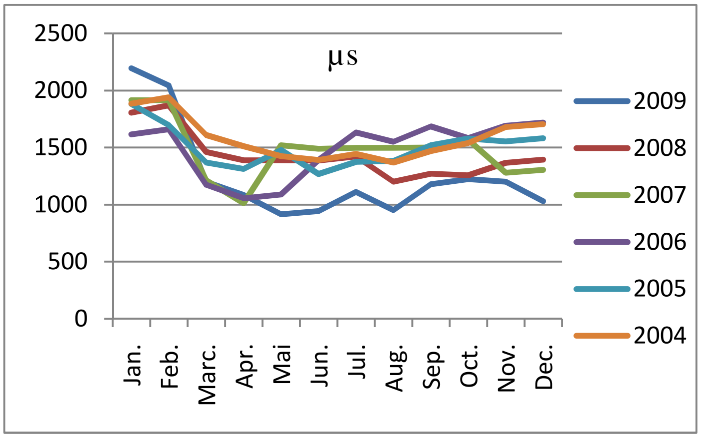


Figure (4-15) the trend of the Electrical Conductivity in the site (1) for years (2004-2009) in the Rosetta branch.

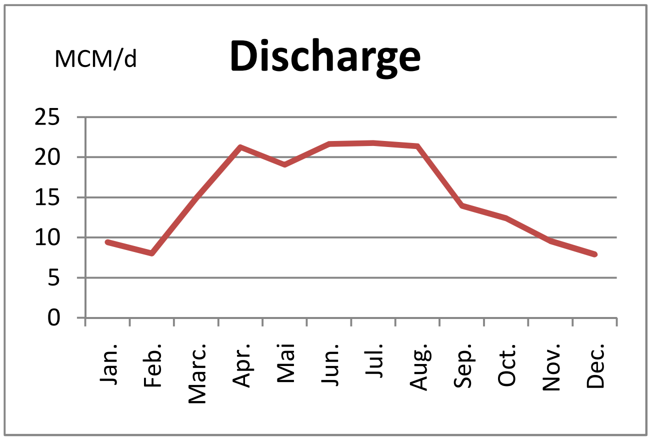


Figure (4-16) the water discharge coming from the upstream, Delta barrage for the year 2009.

It is clear from these two figures (4-15) and (4-16) that, the salinity at the top of its values during January in the years of investigation, and then decreases during February and varies during the second and third quarters of the year then starts to increase again at the fourth quarter of the year. The contrary of this behavior is happening with the water discharge and that is because of the seasonal variation of the water coming from the High Aswan Dam (HAD). So, by increasing the water discharge the water salinity decreases and vice versa. As explained in the introduction chapter, there are around main four Drains discharging agricultural and industrial wastewater directly into the Rosetta branch without the appropriate treatment. This wastewater which is loaded with dissolved and suspended salts is reflecting the Electrical Conductivity in the Rosetta water. The Drains are discharging its wastewater, almost along the year, into Rosetta branch causing an increase in the water salinity. Whilst, the water discharge is changing because of the water effluent into the River Nile increases in the summer as a result of monsoon winds blow in the Ethiopian highlands causing heavy rains which increase the River Nile's water amount

coming into Egypt. Hence, the water discharge, obviously, is the reason behind increasing and decreasing the water salinity concentration in the study area. Regarding the rest four sites, it tends to be the same water salinity trend for the sites from (2) to (5), in figures from (4-17) to (4-20), with difference in the salinity values and the time of opening the gates of the barrage. In the site (1) the salinity values range from 1000-2000µs which is relatively high comparing with the other four sites because it is very close to the upstream of the Idfina barrage.

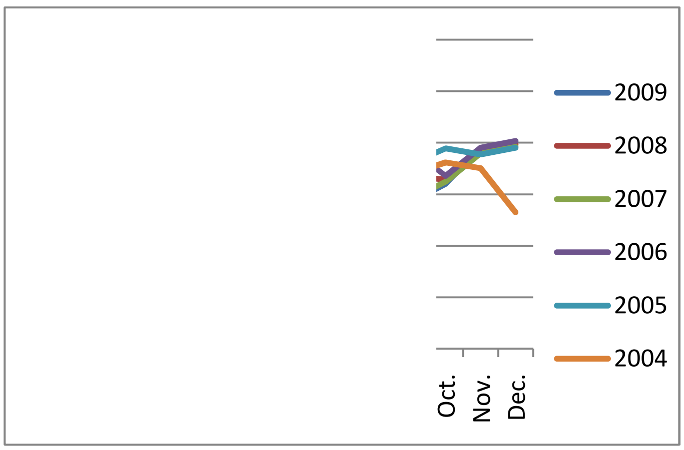


Figure (4-17) the trend of the Electrical Conductivity in the site (2) for years (2004-2009) 2009)
in the Rosetta branch.

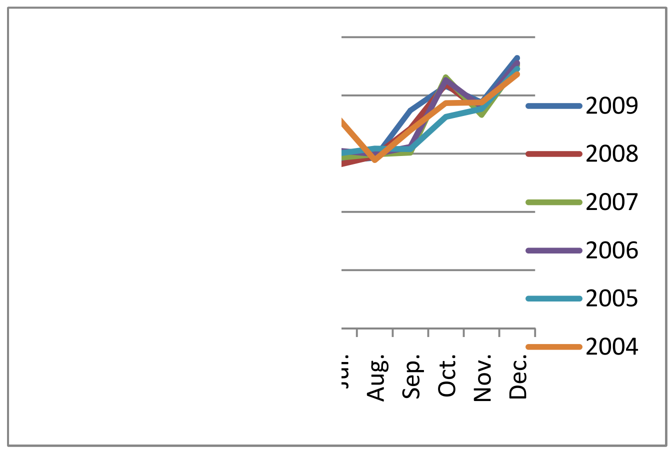


Figure (4-18) the trend of EC in the site (3) for the years (2004-
in The Rosetta branch.

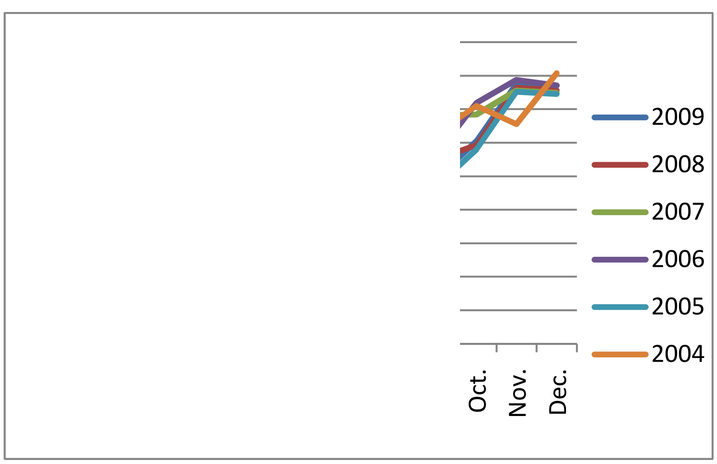


Figure (4-19) the trend of the Electrical

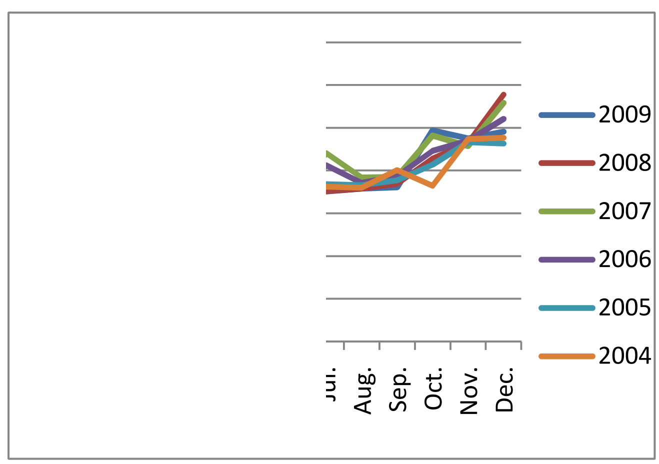


Figure (4-20) the trend of the

Conductivity in the site (4) for years (2004-2009) in Rosetta branch.

EC in the site (5) for the years (2004-2009) in Rosetta branch.

As mentioned in the methodology chapter; there are three hypotheses for the high water salinity values upstream the Barrage of Idfina. One of these hypotheses states that, the source of the salinity is from the wastewater coming from the Drains then goes downstream - with the water flow - and accumulates upstream the Idfina barrage. So, the accumulation of the dissolved salts could be the reason behind high salinity values upstream the barrage of Idfina. But the higher water salinity values during January rather than the rest of the year could be explained as its origin from the salty seawater during opening of the gates at this time and mixing of Mediterranean seawater and freshwater takes place.

By comparing the salinity data upstream Idfina barrage with the downstream one for the year 2009, it was found that the salinity concentration is getting higher upstream during January -the period of opening the gates- and getting lower downstream the barrage of Idfina. It also means that, there is a mixing between the salty water from the sea and River fresh water. Figure (4-21) shows the difference in the salinity values difference between the upstream and downstream sides of Idfina barrage.



Figure (4-21) the difference in the water salinity values upstream and downstream Idfina barrage for the year 2009, in the Rosetta branch.

After the end of January, the gates were closed and the fresh water increased upstream of the barrage causing dilution of the salty water from the sea and the polluted water from the Drains. So the salinity upstream starts to decrease again and after accumulation of the dissolved salts loaded in the water, the EC starts to increase again.

CHAPTER FIVE CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion:

This research investigated the water salinity modeling in the upstream of the barrage of Idfina in Rosetta branch by using MIKE11 model. The main Drains, upstream the barrage of Idfina, were considered during the simulation as point sources. The simulation year used during running the model is 2009. Also EC data histories from the year 2004 to 2009 were used to analysis the water salinity trend in the Rosetta branch upstream the barrage of Idfina. Moreover the water sampling process has been carried out along the Rosetta branch in order to be aware of the current situation of the Rosetta water.

The results calibration and validation of the model indicated that there is a good agreement between the measured and simulated water level, water discharge, and Electrical Conductivity for Rosetta water salinity at three different locations along Rosetta branch.

After summing up the previous results together, the author concluded that the Rosetta branch is under real two risks which are threatening the water quality of the branch. The first one is the polluted wastewater coming from the Drains which are discharging its polluted water into the branch causing water quality deterioration. Consequently, the authority -MWRI - has to open the barrage of Idfina in order to get rid of this deteriorated water and also pass some flooded water. Hence, the second threat comes up, which is the salty seawater downstream the barrage. During opening the barrage of Idfina, the chance of the seawater comes to intrude towards the upstream of Idfina barrage which is in turn increasing the salinity of the water.

For the worse two future scenarios namely 0.5 m and 1.0 m SLR for the years 2050 and 2100 respectively, MIKE11 model was used for the simulation of those two scenarios. It was found that, during opening the barrage of Idfina, the salty water will move up to 10 Km towards the upstream in case 0.5 m SLR and 13 Km in case 1.0 m SLR scenarios.

5.2. Recommendations

The following recommendation could be useful for the adaptation and overcoming the current and future risks of SLR and fresh water deterioration problems;

- It is recommended to make a master plan for sewage treatment with identified target in rural areas using aerobic or anaerobic low cost wastewater treatment plants which should be encouraged with the involvement of private sectors and civil society.
- Indeed, in light of the current water resources scarcity and the problems associated with that topic, it is recommended urgently to promote a culture of planning, organization, direction and control of water resources with the involvement of community participation in the management of water resources.
- Attention to reduce wasting of the fresh water and promoting the projects dealing with the concept of water saving like the West Delta Water Conservation Projects. This project will save 2BCM per year (Sherine S. Ismail, 2008)
- Control the pollution sources on the Rosetta branch, and fresh water resources in general, by applying the appropriate treatment for wastewater before discharging into the fresh water resource. Also reuse the treated wastewater in agriculture could be appropriate to decrease discharging the wastewater on the Rosetta branch.

- Activation of the laws protecting the River Nile from pollution and protecting other water resources in Egypt through continuous follow up and investigations of the water resources and pursuit the violators of these laws.
- Necessity of closing the barrage of Idfena in the face of Mediterranean Seawater invasion to prevent the pollution of the upstream of Rosetta branch.
- Construction of water infrastructure away from the both two mouths of the Nile River - Rosetta and Damietta - by one Km for both River estuaries. Then, rehabilitate the area filled with the saline sea water. That is in order to push the small "sea" - in side Egypt- out and decreasing the bad impacts of this salty water on the groundwater, the fertile Delta agricultural land, and even the urban area inundation.
- Increasing the interest allocation for scientific research by Construction of database unit or department in every ministry responsible for water resources for supporting the researchers to do their researches to be able to develop and create new and effective solutions for and crises related to water or any environmental issues.
- Reusing the wastewater of the Drains after appropriate treatment in artificial discharge for the groundwater in the Delta region in order to overcome Sea water intrusion into the groundwater.

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Appendices

Appendix A: screenshots for the MIKE11 model work

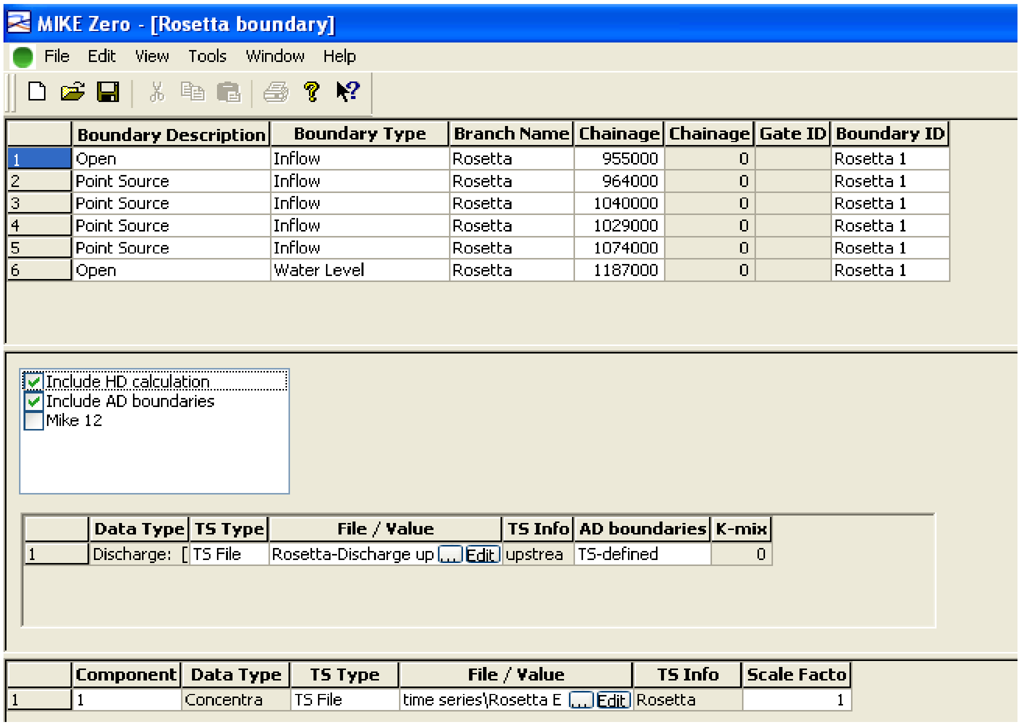


Figure (3-3) Boundary conditions of MIKE 11 of Rosetta branch, Nile River.

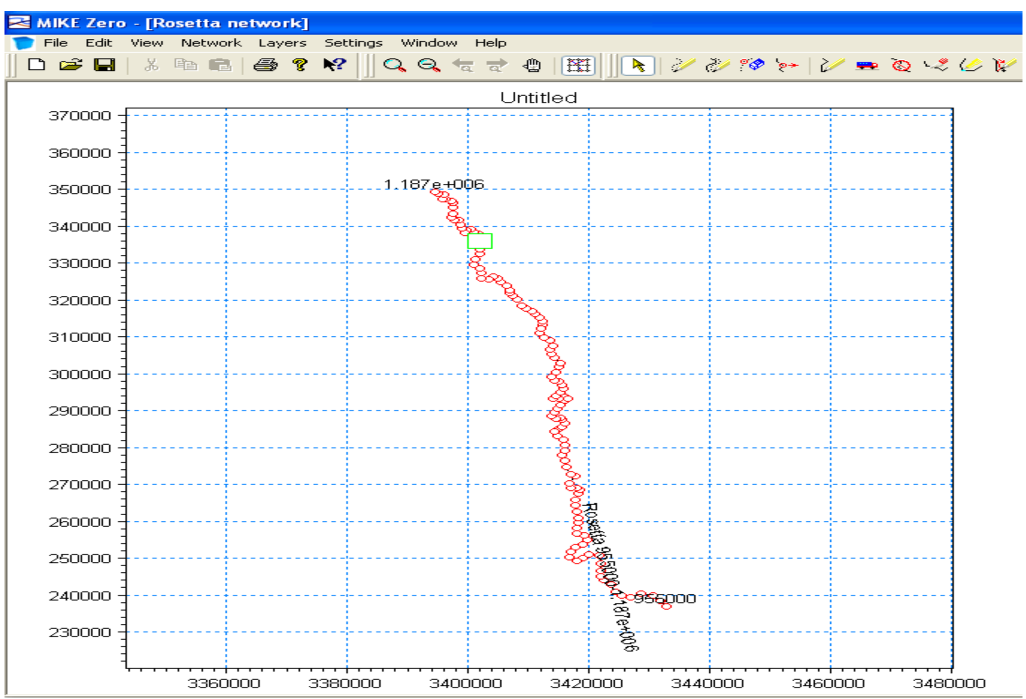


Figure (3-4) Simulation network for the Rosetta branch, Nile River

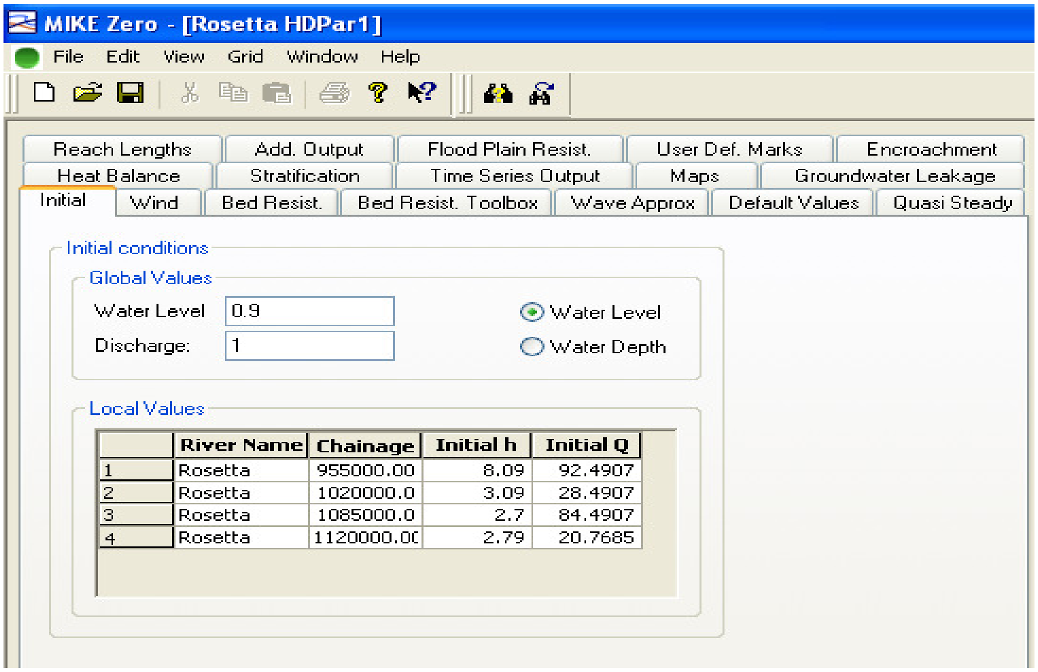


Figure (3-6) Initial conditions for hydrodynamic editor file for the event 2009.

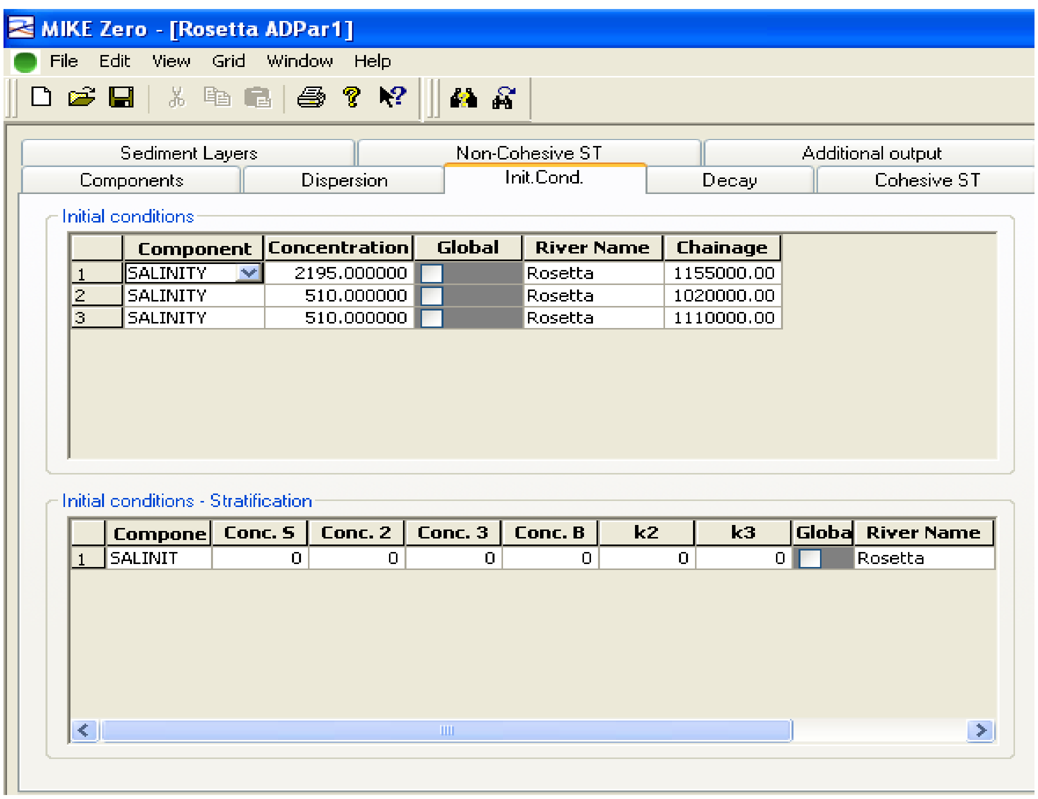


Figure (3-7) initial conditions for advection dispersion editor file for the event 2009.

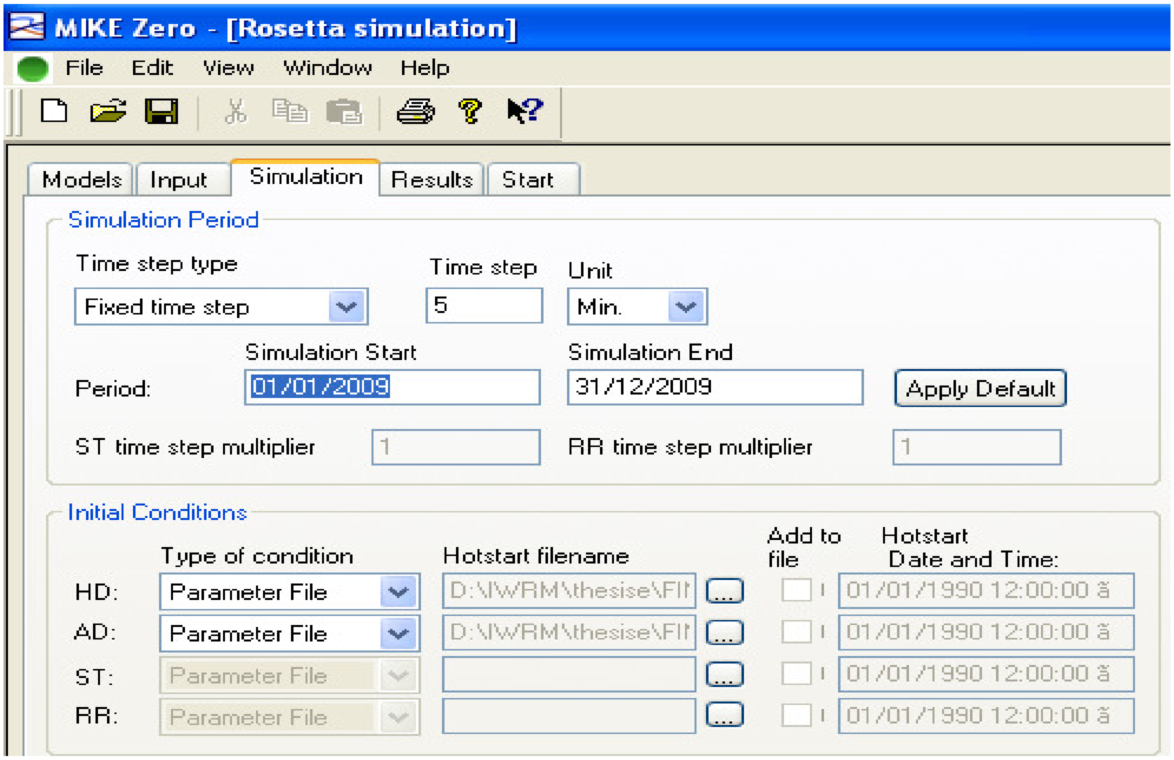


Figure (3-8) Initial conditions of MIKE 11 for the event 2009

Appendix B: measured and collected data

Table (4-4) measured data for water level and water discharge at different chainages. Used for MIKE11 model calibration.

	Water Level m			Water Discharge m3/s		
Date	976000	1020000	1120000	976000	1020000	1120000
01/01/2009	7.47	3.74	2.32	40.49	18.49	84.49
02/01/2009	7.47	3.75	2.32	50.49	38.49	84.49
03/01/2009	7.47	3.75	2.38	60.49	58.49	84.49
04/01/2009	7.47	4.36	2.78	80.49	82.49	84.49
05/01/2009	7.47	4.36	2.81	87.49	82.49	84.49
06/01/2009	7.47	4.36	2.81	87.49	82.49	84.49
07/01/2009	7.47	4.36	2.83	87.49	82.49	84.49
08/01/2009	7.68	4.36	2.84	95.59	90.59	92.59
09/01/2009	7.69	4.36	2.86	100.22	95.22	97.22
10/01/2009	7.83	4.56	2.86	200.92	195.92	197.92
11/01/2009	7.72	4.6	2.89	119.90	122.90	116.90
12/01/2009	7.7	4.6	2.89	106.59	109.59	103.59
13/01/2009	7.71	4.62	2.93	112.95	115.95	109.95
14/01/2009	7.71	4.62	2.93	112.95	115.95	109.95
15/01/2009	7.71	4.62	2.97	112.95	115.95	109.95
16/01/2009	7.73	4.63	2.97	126.26	129.26	123.26
17/01/2009	7.73	4.63	3	126.26	129.26	123.26
18/01/2009	7.73	4.63	3	126.26	129.26	123.26
19/01/2009	7.72	4.62	3.04	119.90	122.90	116.90
20/01/2009	7.73	4.63	3.04	126.26	129.26	123.26
21/01/2009	7.77	4.64	3.08	154.62	157.62	151.62
22/01/2009	7.7	4.63	3.08	106.59	109.59	103.59
23/01/2009	7.7	4.63	3.1	106.59	109.59	103.59
24/01/2009	7.7	4.43	3.03	106.59	109.59	103.59
25/01/2009	7.7	4.42	3.03	106.59	109.59	103.59
26/01/2009	7.7	4.42	3.06	106.59	109.59	103.59
27/01/2009	7.7	4.42	3.07	106.59	109.59	103.59
28/01/2009	7.72	4.43	3.07	119.90	122.90	116.90
29/01/2009	7.72	4.43	3.08	119.90	122.90	116.90
30/01/2009	7.72	4.43	3.08	119.90	122.90	116.90
31/01/2009	7.72	4.42	3.08	119.90	122.90	116.90
01/02/2009	7.72	4.42	3.09	119.90	122.90	116.90
02/02/2009	7.72	4.42	3.09	119.90	122.90	116.90
03/02/2009	7.72	4.43	3.09	119.90	122.90	116.90
04/02/2009	7.72	4.43	3.09	119.90	122.90	116.90
05/02/2009	7.72	4.42	3.09	119.90	122.90	116.90
06/02/2009	7.7	4.44	3.09	107.17	110.17	104.17

07/02/2009	7.69	4.45	3.08	100.22	103.22	97.22
08/02/2009	7.74	4.48	3.07	100.22	103.22	97.22
09/02/2009	7.74	4.48	3.06	100.22	103.22	97.22
10/02/2009	7.52	4.48	3.06	87.49	90.49	84.49
11/02/2009	7.52	4.48	3.06	87.49	90.49	84.49
12/02/2009	7.52	4.35	3.06	87.49	90.49	84.49
13/02/2009	7.52	4.35	3.06	87.49	90.49	84.49
14/02/2009	7.52	4.35	3.05	87.49	90.49	84.49
15/02/2009	7.52	4.35	3.05	87.49	90.49	84.49
16/02/2009	7.52	4.36	3.05	87.49	90.49	84.49
17/02/2009	7.52	4.35	3.04	87.49	90.49	84.49
18/02/2009	7.51	4.35	3.04	81.70	84.70	78.70
19/02/2009	7.52	4.36	3.03	88.65	91.65	85.65
20/02/2009	7.52	4.35	3.03	87.49	90.49	84.49
21/02/2009	7.52	4.36	3.03	87.49	90.49	84.49
22/02/2009	7.52	4.35	3.02	87.49	90.49	84.49
23/02/2009	7.52	4.35	3.02	87.49	90.49	84.49
24/02/2009	7.52	4.36	3.03	87.49	90.49	84.49
25/02/2009	7.52	4.37	3.03	87.49	90.49	84.49
26/02/2009	7.52	4.36	3.04	87.49	90.49	84.49
27/02/2009	7.53	4.36	3.04	93.86	96.86	90.86
28/02/2009	7.53	4.36	3.05	93.86	96.86	90.86
01/03/2009	7.53	4.38	3.05	112.95	107.95	109.95
02/03/2009	7.58	4.85	3.06	111.95	107.95	109.95
03/03/2009	7.68	5.27	3.06	203.60	237.58	239.58
04/03/2009	8.77	5.36	3.06	320.60	328.60	320.60
05/03/2009	8.73	5.32	3.16	283.57	291.57	283.57
06/03/2009	8.71	5.3	3.21	265.63	273.63	265.63
07/03/2009	8.71	5.3	3.21	265.63	273.63	265.63
08/03/2009	8.67	5.26	3.24	230.90	238.90	230.90
09/03/2009	8.72	5.31	3.24	274.31	282.31	274.31
10/03/2009	8.67	5.26	3.25	230.90	238.90	230.90
11/03/2009	8.57	5.16	3.25	151.62	159.62	151.62
12/03/2009	8.14	4.93	3.25	130.21	138.21	130.21
13/03/2009	8.12	4.71	3.25	116.90	124.90	116.90
14/03/2009	8.09	4.72	3.24	97.22	105.22	97.22
15/03/2009	8.13	4.72	3.24	123.26	131.26	123.26
16/03/2009	8.17	4.76	3.22	151.62	166.62	151.62
17/03/2009	8.18	4.77	3.22	159.14	174.14	159.14
18/03/2009	8.18	4.77	3.21	159.14	174.14	159.14
19/03/2009	8.17	4.76	3.21	151.62	166.62	151.62
20/03/2009	8.15	4.74	3.21	137.15	152.15	137.15
21/03/2009	8.15	4.74	3.21	137.15	152.15	137.15

22/03/2009	8.19	4.78	3.21	166.67	181.67	166.67
23/03/2009	8.17	4.76	3.21	151.62	166.62	151.62
24/03/2009	8.14	4.73	3.21	130.21	145.21	130.21
25/03/2009	8.21	4.8	3.21	182.29	197.29	182.29
26/03/2009	8.22	4.81	3.21	189.82	204.82	189.82
27/03/2009	8.17	4.76	3.21	151.62	166.62	151.62
28/03/2009	8.14	4.73	3.21	130.21	145.21	130.21
29/03/2009	8.14	4.73	3.21	130.21	145.21	130.21
30/03/2009	8.14	4.73	3.22	130.21	145.21	130.21
31/03/2009	8.14	4.73	3.22	130.21	145.21	130.21
01/04/2009	8.14	4.73	3.22	130.21	145.21	130.21
02/04/2009	8.18	4.77	3.22	159.14	174.14	159.14
03/04/2009	8.21	4.8	3.21	180.21	195.21	180.21
04/04/2009	8.18	4.77	3.21	159.14	174.14	159.14
05/04/2009	8.17	4.76	3.21	151.62	166.62	151.62
06/04/2009	8.2	4.79	3.21	174.19	189.19	174.19
07/04/2009	8.14	4.8	3.21	182.29	197.29	182.29
08/04/2009	8.12	4.78	3.21	166.67	181.67	166.67
09/04/2009	8.09	4.75	3.22	144.68	159.68	144.68
10/04/2009	8.53	4.79	3.22	174.19	189.19	174.19
11/04/2009	8.58	5.14	3.22	214.12	230.80	214.12
12/04/2009	8.59	5.35	3.23	222.80	230.80	222.80
13/04/2009	8.74	5.35	3.21	222.80	230.80	222.80
14/04/2009	8.91	5.45	3.21	310.76	318.76	310.76
15/04/2009	9	5.47	3.21	329.86	337.86	329.86
16/04/2009	9.01	5.48	3.21	339.12	347.12	339.12
17/04/2009	9	5.47	3.23	329.86	337.86	329.86
18/04/2009	9.04	5.51	3.23	368.63	376.63	368.63
19/04/2009	9	5.47	3.25	329.86	337.86	329.86
20/04/2009	9	5.47	3.25	329.86	337.86	329.86
21/04/2009	9	5.47	3.26	329.86	337.86	329.86
22/04/2009	8.96	5.43	3.26	292.25	300.25	292.25
23/04/2009	8.84	5.38	3.26	248.26	256.26	248.26
24/04/2009	8.69	5.38	3.26	248.26	256.26	248.26
25/04/2009	8.69	5.38	3.26	248.26	256.26	248.26
26/04/2009	8.7	5.39	3.26	256.94	264.94	256.94
27/04/2009	8.69	5.38	3.25	248.26	256.26	248.26
28/04/2009	8.72	5.41	3.25	274.31	282.31	274.31
29/04/2009	8.75	5.44	3.24	301.51	309.51	301.51
30/04/2009	8.76	5.45	3.24	310.76	318.76	310.76
01/05/2009	8.75	5.44	3.24	274.31	282.31	274.31
02/05/2009	8.75	5.44	3.24	274.31	282.31	274.31
03/05/2009	8.77	5.46	3.25	274.31	282.31	274.31

04/05/2009	8.78	5.47	3.25	283.57	291.57	283.57
05/05/2009	8.71	5.4	3.25	274.31	282.31	274.31
06/05/2009	8.75	5.44	3.25	222.80	230.80	222.80
07/05/2009	8.72	5.41	3.25	159.14	167.14	159.14
08/05/2009	8.74	5.43	3.25	292.25	300.25	292.25
09/05/2009	8.74	5.43	3.25	292.25	300.25	292.25
10/05/2009	8.73	5.42	3.25	283.57	291.57	283.57
11/05/2009	8.73	5.42	3.24	283.57	291.57	283.57
12/05/2009	8.7	5.39	3.24	256.94	264.94	256.94
13/05/2009	8.65	5.34	3.24	214.12	222.12	214.12
14/05/2009	8.65	5.34	3.24	214.12	222.12	214.12
15/05/2009	8.68	5.37	3.25	239.58	247.58	239.58
16/05/2009	8.68	5.37	3.25	239.58	247.58	239.58
17/05/2009	8.54	5.33	3.24	206.02	214.02	206.02
18/05/2009	8.08	5.27	3.24	159.14	167.14	159.14
19/05/2009	8.06	5.25	3.24	144.68	152.68	144.68
20/05/2009	8	4.89	3.24	103.59	111.59	103.59
21/05/2009	8.05	4.94	3.23	137.15	145.15	137.15
22/05/2009	8.07	4.96	3.23	151.62	159.62	151.62
23/05/2009	8.5	4.99	3.22	174.19	182.19	174.19
24/05/2009	8.52	5.26	3.22	179.82	187.82	189.82
25/05/2009	8.54	5.28	3.22	206.02	204.02	206.02
26/05/2009	8.55	5.29	3.21	214.12	221.12	214.12
27/05/2009	8.55	5.29	3.21	214.12	221.12	214.12
28/05/2009	8.55	5.29	3.21	214.12	221.12	214.12
29/05/2009	8.55	5.29	3.21	214.12	221.12	214.12
30/05/2009	8.55	5.34	3.22	214.12	221.12	214.12
31/05/2009	8.55	5.34	3.22	214.12	221.12	214.12
01/06/2009	8.55	5.34	3.22	214.12	221.12	214.12
02/06/2009	8.55	5.34	3.22	214.12	221.12	214.12
03/06/2009	8.57	5.36	3.23	230.90	237.90	230.90
04/06/2009	8.57	5.36	3.23	230.90	237.90	230.90
05/06/2009	8.57	5.36	3.23	230.90	237.90	230.90
06/06/2009	8.68	5.37	3.23	239.58	246.58	239.58
07/06/2009	8.68	5.37	3.23	239.58	246.58	239.58
08/06/2009	8.68	5.37	3.23	239.58	246.58	239.58
09/06/2009	8.68	5.37	3.23	239.58	246.58	239.58
10/06/2009	8.77	5.37	3.23	239.58	246.58	239.58
11/06/2009	8.78	5.38	3.23	248.26	255.26	248.26
12/06/2009	8.79	5.39	3.23	256.94	263.94	256.94
13/06/2009	8.79	5.39	3.23	256.94	263.94	256.94
14/06/2009	8.79	5.39	3.23	256.94	263.94	256.94
15/06/2009	8.79	5.39	3.25	256.94	263.94	256.94

16/06/2009	8.79	5.39	3.24	256.94	263.94	256.94
17/06/2009	8.79	5.39	3.25	256.94	263.94	256.94
18/06/2009	8.79	5.39	3.25	256.94	263.94	256.94
19/06/2009	8.79	5.39	3.26	256.94	263.94	256.94
20/06/2009	8.79	5.39	3.26	256.94	263.94	256.94
21/06/2009	8.8	5.4	3.25	265.63	272.63	265.63
22/06/2009	8.8	5.4	3.25	265.63	272.63	265.63
23/06/2009	8.8	5.4	3.24	265.63	272.63	265.63
24/06/2009	8.8	5.4	3.26	265.63	272.63	265.63
25/06/2009	8.8	5.4	3.25	265.63	272.63	265.63
26/06/2009	8.8	5.4	3.26	265.63	272.63	265.63
27/06/2009	8.8	5.4	3.24	265.63	272.63	265.63
28/06/2009	8.8	5.4	3.24	265.63	272.63	265.63
29/06/2009	8.79	5.39	3.25	256.94	263.94	256.94
30/06/2009	8.79	5.39	3.25	256.94	263.94	256.94
01/07/2009	8.79	5.39	3.25	256.94	263.94	256.94
02/07/2009	8.79	5.39	3.26	256.94	263.94	256.94
03/07/2009	8.79	5.39	3.25	256.94	263.94	256.94
04/07/2009	8.79	5.39	3.26	256.94	263.94	256.94
05/07/2009	8.78	5.38	3.26	248.26	255.26	248.26
06/07/2009	8.78	5.38	3.26	248.26	255.26	248.26
07/07/2009	8.78	5.38	3.25	248.26	255.26	248.26
08/07/2009	8.78	5.38	3.26	248.26	255.26	248.26
09/07/2009	8.78	5.38	3.26	248.26	255.26	248.26
10/07/2009	8.78	5.38	3.25	248.26	255.26	248.26
11/07/2009	8.77	5.37	3.25	239.58	246.58	239.58
12/07/2009	8.78	5.38	3.26	248.26	255.26	248.26
13/07/2009	8.78	5.38	3.25	248.26	255.26	248.26
14/07/2009	8.78	5.38	3.25	248.26	255.26	248.26
15/07/2009	8.78	5.38	3.25	248.26	255.26	248.26
16/07/2009	8.78	5.38	3.25	248.26	255.26	248.26
17/07/2009	8.77	5.37	3.25	239.58	246.58	239.58
18/07/2009	8.77	5.37	3.26	239.58	246.58	239.58
19/07/2009	8.77	5.37	3.24	239.58	246.58	239.58
20/07/2009	8.77	5.37	3.24	239.58	246.58	239.58
21/07/2009	8.77	5.37	3.24	239.58	246.58	239.58
22/07/2009	8.78	5.38	3.24	248.26	255.26	248.26
23/07/2009	8.78	5.38	3.27	248.26	255.26	248.26
24/07/2009	8.78	5.38	3.27	248.26	255.26	248.26
25/07/2009	8.79	5.39	3.24	256.94	263.94	256.94
26/07/2009	8.8	5.4	3.24	265.63	272.63	265.63
27/07/2009	8.8	5.4	3.24	265.63	272.63	265.63
28/07/2009	8.81	5.41	3.24	274.31	281.31	274.31

29/07/2009	8.8	5.4	3.24	265.63	272.63	265.63
30/07/2009	8.8	5.4	3.24	265.63	272.63	265.63
31/07/2009	8.8	5.4	3.24	265.63	272.63	265.63
01/08/2009	8.79	5.39	3.24	256.94	263.94	256.94
02/08/2009	8.79	5.39	3.24	256.94	263.94	256.94
03/08/2009	8.79	5.39	3.24	256.94	263.94	256.94
04/08/2009	8.79	5.39	3.24	256.94	263.94	256.94
05/08/2009	8.79	5.39	3.24	256.94	263.94	256.94
06/08/2009	8.79	5.39	3.24	256.94	263.94	256.94
07/08/2009	8.79	5.39	3.24	256.94	263.94	256.94
08/08/2009	8.79	5.39	3.24	256.94	263.94	256.94
09/08/2009	8.78	5.38	3.24	248.26	255.26	248.26
10/08/2009	8.78	5.38	3.24	248.26	255.26	248.26
11/08/2009	8.79	5.39	3.24	256.94	263.94	256.94
12/08/2009	8.79	5.39	3.24	256.94	263.94	256.94
13/08/2009	8.79	5.39	3.21	256.94	263.94	256.94
14/08/2009	8.79	5.39	3.21	256.94	263.94	256.94
15/08/2009	8.78	5.38	3.21	248.26	255.26	248.26
16/08/2009	8.78	5.38	3.21	248.26	255.26	248.26
17/08/2009	8.79	5.39	3.21	256.94	263.94	256.94
18/08/2009	8.79	5.39	3.21	256.94	263.94	256.94
19/08/2009	8.79	5.39	3.21	256.94	263.94	256.94
20/08/2009	8.66	5.35	3.21	222.80	229.80	222.80
21/08/2009	8.64	5.33	3.21	206.02	213.02	206.02
22/08/2009	8.64	5.33	3.21	206.02	213.02	206.02
23/08/2009	8.7	5.39	3.22	256.94	263.94	256.94
24/08/2009	8.68	5.37	3.22	239.58	246.58	239.58
25/08/2009	8.69	5.38	3.21	248.26	255.26	248.26
26/08/2009	8.69	5.38	3.21	248.26	255.26	248.26
27/08/2009	8.69	5.38	3.21	248.26	255.26	248.26
28/08/2009	8.68	5.37	3.21	239.58	246.58	239.58
29/08/2009	8.67	5.37	3.22	239.58	246.58	239.58
30/08/2009	8.67	5.36	3.22	230.90	237.90	230.90
31/08/2009	8.67	5.36	3.22	230.90	237.90	230.90
01/09/2009	8.65	5.35	3.22	222.80	229.80	222.80
02/09/2009	8.65	5.34	3.22	214.12	231.12	214.12
03/09/2009	8.57	5.31	3.22	189.82	196.82	189.82
04/09/2009	8.41	5.3	3.21	182.29	189.29	182.29
05/09/2009	8.33	5.07	3.21	197.92	204.92	197.92
06/09/2009	8.33	5.05	3.21	197.92	204.92	197.92
07/09/2009	8.32	5.04	3.21	189.82	196.82	189.82
08/09/2009	8.29	5.01	3.2	166.67	173.67	166.67
09/09/2009	8.29	5.01	3.2	166.67	173.67	166.67

10/09/2009	8.26	4.98	3.2	144.68	151.68	144.68
11/09/2009	8.28	5	3.2	159.14	166.14	159.14
12/09/2009	8.28	5	3.2	159.14	166.14	159.14
13/09/2009	8.29	5.01	3.19	166.67	173.67	166.67
14/09/2009	8.3	5.02	3.19	174.19	181.19	174.19
15/09/2009	8.32	5.29	3.19	189.82	196.82	189.82
16/09/2009	8.07	4.77	3.19	151.62	158.62	151.62
17/09/2009	8.07	4.76	3.19	151.62	158.62	151.62
18/09/2009	8.07	4.76	3.19	151.62	158.62	151.62
19/09/2009	8.06	4.75	3.19	144.68	151.68	144.68
20/09/2009	8.06	4.75	3.19	144.68	151.68	144.68
21/09/2009	8.06	4.75	3.19	144.68	151.68	144.68
22/09/2009	8.06	4.74	3.19	144.68	151.68	144.68
23/09/2009	8.06	4.73	3.19	144.68	151.68	144.68
24/09/2009	8.04	4.73	3.19	130.21	137.21	130.21
25/09/2009	8.04	4.73	3.18	130.21	137.21	130.21
26/09/2009	8.04	4.72	3.18	130.21	137.21	130.21
27/09/2009	8.04	4.71	3.18	130.21	137.21	130.21
28/09/2009	8.06	4.73	3.18	144.68	151.68	144.68
29/09/2009	8.06	4.73	3.18	144.68	151.68	144.68
30/09/2009	8.04	4.71	3.18	130.21	137.21	130.21
01/10/2009	8.03	4.7	3.18	123.26	130.26	123.26
02/10/2009	8.02	4.69	3.18	116.90	123.90	116.90
03/10/2009	7.82	4.69	3.18	116.90	123.90	116.90
04/10/2009	7.82	4.69	3.18	116.90	123.90	116.90
05/10/2009	7.82	4.69	3.18	116.90	123.90	116.90
06/10/2009	7.82	4.69	3.18	116.90	123.90	116.90
07/10/2009	7.82	4.69	3.17	116.90	123.90	116.90
08/10/2009	7.82	4.69	3.17	116.90	123.90	116.90
09/10/2009	7.82	4.69	3.17	116.90	123.90	116.90
10/10/2009	8.02	4.69	3.17	116.90	123.90	116.90
11/10/2009	8.04	4.71	3.17	130.21	137.21	130.21
12/10/2009	8.05	4.72	3.17	137.15	144.15	137.15
13/10/2009	8.05	4.72	3.17	137.15	144.15	137.15
14/10/2009	8.06	4.73	3.17	144.68	151.68	144.68
15/10/2009	8.12	4.74	3.17	151.62	158.62	151.62
16/10/2009	8.12	4.74	3.17	151.62	158.62	151.62
17/10/2009	8.13	4.75	3.17	151.62	158.62	151.62
18/10/2009	8.15	4.77	3.17	159.14	166.14	159.14
19/10/2009	8.16	4.78	3.18	174.19	181.19	174.19
20/10/2009	8.16	4.78	3.18	182.29	189.29	182.29
21/10/2009	8.14	4.76	3.18	182.29	189.29	182.29
22/10/2009	8.13	4.75	3.18	166.67	173.67	166.67

23/10/2009	8.13	4.75	3.19	159.14	166.14	159.14
24/10/2009	8.12	4.74	3.19	159.14	166.14	159.14
25/10/2009	8.12	4.74	3.19	151.62	158.62	151.62
26/10/2009	8.13	4.75	3.19	151.62	158.62	151.62
27/10/2009	8.15	4.77	3.19	159.14	166.14	159.14
28/10/2009	8.13	4.75	3.19	174.19	181.19	174.19
29/10/2009	8.12	4.74	3.19	159.14	166.14	159.14
30/10/2009	8.11	4.73	3.19	151.62	158.62	151.62
31/10/2009	8.1	4.72	3.19	144.68	151.68	144.68
01/11/2009	8.06	4.73	3.19	144.68	151.68	144.68
02/11/2009	8.06	4.73	3.19	144.68	151.68	144.68
03/11/2009	8.08	4.75	3.19	159.14	166.14	159.14
04/11/2009	8.06	4.73	3.19	144.68	151.68	144.68
05/11/2009	8.04	4.71	3.19	130.21	137.21	130.21
06/11/2009	7.9	4.67	3.07	103.59	110.59	103.59
07/11/2009	7.7	4.42	3.08	103.59	110.59	103.59
08/11/2009	7.7	4.42	3.07	103.59	110.59	103.59
09/11/2009	7.7	4.42	3.07	103.59	110.59	103.59
10/11/2009	7.69	4.39	3.07	97.22	104.22	97.22
11/11/2009	7.69	4.39	3.07	97.22	104.22	97.22
12/11/2009	7.69	4.39	3.06	97.22	104.22	97.22
13/11/2009	7.69	4.39	3.06	97.22	104.22	97.22
14/11/2009	7.69	4.39	3.06	97.22	104.22	97.22
15/11/2009	7.69	4.39	3.06	97.22	104.22	97.22
16/11/2009	7.68	4.38	3.05	90.86	97.86	90.86
17/11/2009	7.68	4.38	3.05	90.86	97.86	90.86
18/11/2009	7.69	4.39	3.05	97.22	104.22	97.22
19/11/2009	7.69	4.39	3.05	97.22	104.22	97.22
20/11/2009	7.69	4.39	3.05	97.22	104.22	97.22
21/11/2009	7.69	4.39	3.05	97.22	104.22	97.22
22/11/2009	7.69	4.39	3.05	97.22	104.22	97.22
23/11/2009	7.69	4.39	3.05	97.22	104.22	97.22
24/11/2009	7.69	4.39	3.05	97.22	104.22	97.22
25/11/2009	7.71	4.41	3.05	109.95	116.95	109.95
26/11/2009	7.75	4.45	3.05	137.15	144.15	137.15
27/11/2009	7.75	4.45	3.05	137.15	144.15	137.15
28/11/2009	7.74	4.44	3.05	130.21	137.21	130.21
29/11/2009	7.69	4.39	3.05	130.21	137.21	130.21
30/11/2009	7.7	4.4	3.05	97.22	104.22	97.22
01/12/2009	7.69	4.39	3.06	97.22	104.22	97.22
02/12/2009	7.69	4.39	3.06	97.22	104.22	97.22
03/12/2009	7.68	4.39	3.06	90.86	97.86	90.86
04/12/2009	7.68	4.38	3.06	90.86	97.86	90.86

05/12/2009	7.68	4.38	3.06	90.86	97.86	90.86
06/12/2009	7.68	4.38	3.06	90.86	97.86	90.86
07/12/2009	7.68	4.38	3.06	90.86	97.86	90.86
08/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
09/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
10/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
11/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
12/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
13/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
14/12/2009	7.69	4.39	3.05	90.86	97.86	90.86
15/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
16/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
17/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
18/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
19/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
20/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
21/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
22/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
23/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
24/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
25/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
26/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
27/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
28/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
29/12/2009	7.68	4.38	3.05	90.86	97.86	90.86
30/12/2009	7.69	4.39	3.05	97.22	104.22	97.22
31/12/2009	7.68	4.38	3.05	90.86	97.86	90.86

Table (4-5) Electrical Conductivity values used for exploratory data analysis

location	month	2009	2008	2007	2006	2005	2004
Site 1	Jan.	2195	1805	1915	1615	1882	1885
Site 1	Feb.	2043	1870	1915	1660	1697	1941
Site 1	Marc.	1197	1461	1212	1172	1370	1609
Site 1	Apr.	1083	1389	1014	1056	1313	1513
Site 1	Mai	916	1388	1519	1090	1479	1424
Site 1	Jun.	942	1386	1490	1391	1268	1390
Site 1	Jul.	1110	1421	1497	1631	1375	1445
Site 1	Aug.	952	1202	1498	1551	1383	1369
Site 1	Sep.	1179	1271	1500	1685	1519	1469
Site 1	Oct.	1224	1257	1569	1582	1578	1540
Site 1	Nov.	1201	1367	1279	1692	1555	1680

Site 1	Dec.	1030	1393	1305	1718	1581	1706
Site 2	Jan.	685	705	795	804	882	995
Site 2	Feb.	741	770	795	849	697	843
Site 2	Marc.	709	561	792	561	570	697
Site 2	Apr.	613	489	594	445	513	583
Site 2	Mai	524	488	599	479	679	416
Site 2	Jun.	490	486	570	480	468	442
Site 2	Jul.	545	521	577	720	575	610
Site 2	Aug.	469	602	578	640	583	452
Site 2	Sep.	569	671	580	774	719	679
Site 2	Oct.	640	657	649	671	778	724
Site 2	Nov.	780	767	759	781	755	701
Site 2	Dec.	806	793	785	807	781	530
Site 3	Jan.	886	787	937	827	756	829
Site 3	Feb.	872	757	866	888	888	861
Site 3	Marc.	743	753	513	571	513	797
Site 3	Apr.	700	699	666	669	586	727
Site 3	Mai	522	613	614	571	469	590
Site 3	Jun.	568	626	567	596	603	605
Site 3	Jul.	576	562	586	610	601	717
Site 3	Aug.	585	591	598	599	617	578
Site 3	Sep.	748	685	603	623	615	680
Site 3	Oct.	831	839	862	852	726	773
Site 3	Nov.	776	744	733	760	754	775
Site 3	Dec.	928	908	902	911	891	872
Site 4	Jan.	708	635	816	606	683	765
Site 4	Feb.	740	767	745	836	742	751
Site 4	Marc.	676	465	545	632	725	622
Site 4	Apr.	606	496	446	578	440	579
Site 4	Mai	469	482	465	492	471	401
Site 4	Jun.	596	480	482	505	457	447
Site 4	Jul.	559	494	541	441	455	455
Site 4	Aug.	552	555	612	470	471	464
Site 4	Sep.	494	550	681	564	469	627
Site 4	Oct.	605	592	684	718	580	710
Site 4	Nov.	777	764	756	787	752	655
Site 4	Dec.	770	757	749	771	745	807
Site 5	Jan.	505	514	493	509	505	524
Site 5	Feb.	447	504	593	499	473	477
Site 5	Marc.	455	456	446	430	388	428
Site 5	Apr.	414	411	367	405	428	393

Site 5	Mai	342	345	371	367	370	383
Site 5	Jun.	342	331	338	341	350	343
Site 5	Jul.	351	352	441	412	368	362
Site 5	Aug.	358	358	384	371	366	360
Site 5	Sep.	361	369	385	387	377	401
Site 5	Oct.	494	428	482	446	414	364
Site 5	Nov.	475	465	457	470	466	474
Site 5	Dec.	491	578	558	521	463	477

Appendix C: Declaration

I Mustafa El-Morshdy; declare hereby on oath that this Master Thesis in hand has been made independently and without the help of any other than acknowledged.

The thoughts taken directly or indirectly from external sources are made recognizable as such. This thesis was not presented to any other examination authority either in the same or similar form and till now it has not been published.

I do further agree to a later publication of this Master Thesis, may it be in parts or entirely within the ITT publications.

Signature

نمذجة تسرب مياه البحر الي فرع رشيد، دلتا نهر النيل، مصر

أعداد
مصطفي المرشدي

المشرف
دكتورعباس العمري

المشرف المساعد
دكتور لارس ريبا

ملخص

تسرب المياه المالحة هو قضية رئيسية بالنسبة لمصبات الأنهار الواقعة على البحر أو المحيط وملوحة مياه النهر هو الصفه المميزه بسبب تداخل مياه البحر. تم استخدام نموذج أحادي البعد لمحاكاة أثر ارتفاع مستوى سطح البحر على نوعية مياه فرع رشيد من حيث التوصيليه الكهربيه. هذا البحث يشير الي عملية تداخل مياه البحر ويوضح إلى أي حد تدخل المياه المالحة القادمة من البحر الأبيض المتوسط .تم استخدام نموذج مايك 11 من أجل تقييم أثر أرتفاع مستوى سطح البحر على المياه العذبه أعلي التيار والتنبؤ بالتأثيرات المستقبلية لسيناريوهين أرتفاع مستوي سطح البحر وهما نصف متر ومتر فوق مستوى مياه البحر الحاليه.

أستخدمت البيانات زمني التحقيق الميداني عن التوصيليه الكهربيه وتصرف مياه فرع رشيد في هذه الدراسة لتوضيح تغير ملوحة المياه في فرع رشيد أعلي تيار قناطر أدفينا التى تمنع غزو المياه المالحة التى تأتى من البحرة اثناء فتح القناطر.

النتائج أيضا تساعد على اتخاذ نوعية المياه باعتبارها مسألة خطيرة لتجنب تسرب المياه المالحة وأثرها على الأنشطة الاجتماعية والاقتصادية خصوصا في ظل مشاكل ندرة المياه في العالم.